GEOMORPHOLOGICAL MAPPING AND LANDFORM ANALYSIS IN CENTRAL SAUDI ARABIA : WITH SPECIAL REFERENCE TO THE CHARACTERISTICS OF PEDIMENTS AND FANS

Z. M. N. Munshi

A Thesis Submitted for the Degree of PhD
at the
University of St Andrews

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'GEOMORPHOLOGICAL MAPPING AND LANDFORM ANALYSIS IN CENTRAL SAUDI ARABIA'

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Volume I (text)

By

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CONTENTS

Volume I (Text)

Volume II (Tables, figures, and plates)

List of Tables

<u>List of figures:</u>

List of Plates:

Volume III (Maps and diagrams)

List of figures:

ABSTRACT

The aim of this study is to seek for a more detailed understanding of the geomorphology of some parts of Central Saudi Arabia, on the basis of aerial photographic interpretation, field surveys and investigation, and data obtained by field and laboratory analysis.

An introduction to the study area is given together with an account of the geology and physiography of Saudi Arabia and especially the study area based upon drilling, field studies, and records from a variety of sources (Vol. I; Ch. 1).

A procedure for geomorphological mapping is discussed together with a review of the principles, problems, methods, and development of geomorphological mapping (Vol. I, Ch. 2 and App. A). Following these principles and methods, geomorphological maps have been compiled on the basis of the interpretation of air photographs, field surveys and investigation, and laboratory analysis of surface materials (Vol. III, figs. 12a - 15b).

An attempt has been made to compare the method of geomorphological mapping with the results of landform classification including discussion of the application of the Land System approach to the area (Vol. I, Ch. 3). The landform classification has been tabulated (Vol. II, tables 9 - 11) and the maps are presented (Vol. III, figs. 16 - 20) to show the major landform systems and units with a sample area showing the smaller units (landform type units) of the landforms.

Particle/

Particle size analysis and pebble shape were employed to give some information about deposition and transportation on selected pediments and alluvial fans. A discussion and critical reviews of relevant literature on the theory of sieving and sedimentation are given (Vol. I, App. B). This is followed by an introduction to the procedure for field and laboratory methods of particle size analysis and pebble shape measurements (Vol. I, Ch. 4).

The terminology for piedmont surfaces is discussed to clarify some of the confusion concerning the use of such terms. This is followed by a review of the theories concerning pediment formation, development, and their relationships to other landforms (Vol. I, Ch. 5). The particle sizes of samples taken from pediments and the shapes of pebbles derived from these pediments have been measured, analysed, and discussed in relation to pediment, slope, distance from the mountain fronts and depth (Vol. I, Ch. 5, Vol. II tables 15 - 92, figs. 78 - 110, pl. 1 - 8, and Vol. III figs. 21 - 45b).

Alluvial fans are another type of the landforms which are discussed in detail. They are well developed in the south-western parts of the study area where they form a series of confluent alluvial fans (bahada). Terminology and the theory of fan formation is discussed on the basis of field investigation and aerial photographic interpretation together with reviews of relevant literature (Vol. I, Ch. 6). Size analysis of fan deposits as well as pebble shape are once again used to obtain information about transportation and deposition (Vol. I, Ch. 6, Vol. II tables 93 - 147, figs./

figs. 111 - 140, pl. 9 - 16, and Vol. III figs 46 - 77).

Finally these studies are considered in relation to indications of climatic changes within Central Saudi Arabia. Problems of geomorphological mapping and interpretation are discussed and short accounts given of future work needed for detailed understanding of the desert landscape through the regional analysis of the landforms of a part of Central Saudi Arabia (conclusions).

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I owe special debts of gratitude to Dr. K. McIver of the Geography Department, St. Andrews University, not only for helping with some financial difficulties, but also for writing in support of my field programme.

DECLARATION

I hereby declare that this thesis is the record of original research and higher study carried out and composed by myself (Z.M.N.Munshi) ; a research student admitted under Ordinance General No.12 on the 1st,January, 1968, and a candidate for the degree of Doctor of Philosophy under Ordinance General No.12 on the 30th,April,1969, at the University of St.Andrews.

I further confirm that this thesis has not been accepted in any previous application for a higher degree.

As supervisor to Mr. Z.M.N.Munshi's research project I confirm that the above declaration is correct and that the conditions of the Ordinance and Regulations have been fulfiled.

Michael F. Thomas

Dr. M.F.Thomas.

INTRODUCTION

INTRODUCTION

The major theme of this thesis is to use aerial photographic interpretation as a method for semi-detailed geomorphological mapping, landform classification, and landform mapping. The purpose of this kind of enquiry is to provide as much information about the geomorphology of the study area as possible for academic interest as well as practical application. To achieve this purpose, the availability of the necessary material for mapping, such as aerial photographs, and geologic and topographic maps, has to be first considered. Accordingly, the area of study has been selected so that the medium size aerial photographs, controlled photo-mosaics, and geologic and topographic maps for the area are obtainable.

The selected area of study is part of Southern Najed, Central Saudi Arabia (for location of the study area see figs. 1, 3, 4 and 5). However, the location of the area of study as well as its geological and physiographical backgrounds is the major topic of chapter 1.

Mapping the results of this work has involved a number of different problems. Foremost among these is the question of scale. The aerial photographs are approximately 1:60,000 and the controlled photo-mosaics are 1:50,000. The landform maps presented are at a scale of approximately 1:100,000. This scale was selected because it is close to the original mapping scale, thus allowing representation of most of the detail, and also the convenience in handling of the final maps. At most scales, the smaller units of the landform/

landform cannot be displayed. A decision therefore had to be taken concerning the content and character of the maps.

An attempt has been made to produce sketch maps that by means of analysis would form semi-detailed geomorphological maps based on mapping techniques discussed in chapter 2, and appendix A. From these maps terrain units have been identified and classified and these have been separately shown at the landform system level (chapter 3).

These documents may serve several purposes. In particular they draw attention to the diversity of the map of arid terrain patterns, and to some particular problems of interpretation. They may also be valuable in their own right as a basis for hydrologic or other resource overlays.

In this thesis the mapping programme has led to a further (field) enquiry into the nature of fans and pediments in the arid landscape; essentially concerned with the problem of definition and identification of the two forms from aerial photographs. This has been allowed to develop into a detailed analytical study of two major landform types (Part two of the thesis), extending both the range of the programme from the description to an analytical stage, and further permitting some discussion of the development of these landforms.

The concept of descriptive landform analysis, of landform types and landform type regions, has received the major attention of Geographers, Geologists, and Geomorphologists from early 1800 until recent years (see Linton, 1951). Kesseli (1946) suggested that geographers should practice the art of Geomorphology, that is the art of terrain description, without concern/

concern for the origin of the land. The best means, according to him, to establish a true geographical geomorphology is to study the assemblage of geomorphic landscape. Kesseli's arguments (1954 : the 50th anniversary meeting of the Association of American Geographers, vol. 44, pp. 220-221) about geomorphological studies for the needs of Geographers, were abstracted as follows:

"a- that this desired geomorphology need not concern itself with origin of the landforms; b- that this geographic geomorphology should divorce itself from an explanatory terminology and use a descriptive terminology instead; c- that this geomorphology could be developed by recognizing and defining landform types, a procedure which would follow the methods applied in the investigation of climate, vegetation, and soil; d- that the landforms themselves should be mapped by the use of appropriate symbols, following methods used by European geomorphologists in constructing morphogeographic maps; and e- that physical as well as human geographers could contribute to the development of this desired geographic geomorphology".

Kesseli was supported to a great extent by Hammond (1954a, 1954b, 1962 & 1964), who devoted himself to establish an empirical quantitative landform analysis, and to explain and analyse the landforms in relation to other physical and cultural phenomena.

Strahler (1954, p. 7 & 8), believed that both explanatory and quantitative landform studies should be added to the geographic training; "the explanatory descriptive method should be used in introductory geography courses where cultural aims of a general education paramount... The empirical quantitative method/

method should be used principally by the specialist investigating geographical research problems and is the only way in which the information can be handled for statistical and mathematical analysis. Rather than rejecting one method in favour of the other, the modern geographer might well give more attention to cultivating both far more vigorously than he has thus far".

Robinson (1963), stressed both the study of geomorphic processes and the the statistical descriptive analysis. The debates on whether descriptive geomorphology should be empirical or explanatory have attracted the attention of many other authors such as Bryan (1950), Mather (1950), Leighly (1955), Ward (1955) and Weaver (1965).

The search for geographical geomorphology has revealed no clear agreement as to the nature of the subject among the American geomorphologists, geographers or geologists. But as an objective description of the landforms, I believe it should be at least the first task in any landform analysis.

If the first step taken in any regional study of the landforms was to tell us what, where, and how much, we can then utilise the information obtained for genetic analysis; regional and/or geomorphic process on one hand, and for functional analysis on the other hand. This type of framework for landform studies fits well into the geographic studies of areal differentiation and can offer the type of information which most workers seek.

Large-scale morphological analysis is usually based on the natural units; environmental as introduced by Bourne (1931), or morphological as introduced by Linton (1951) and adapted and modified by Waters (1958) and Savigear/

Savigear (1965), (see also Leuder, 1959, for landform unit definition, and Thomas, 1969).

In most recent morphological analyses of the land units, the drainage basin has been most frequently used as the natural unit. The relationships that can be established between the properties of a unit are between quantities such as stream length, stream order, and the slope. These variables can then be related to one another quantitatively or dimensionally. But the major problem is the great complexity of nearly all units of the landscape which have been formed as the result of the interaction of different variables. To keep these variables, as far as possible, under control, however, it is more reasonable to deal with only one element of a particular unit at a time under one condition; that is to say slope on one rock type or under one climatic environment.

Mapping the landforms is the first basic requirement for any geomorphological purpose specially in areas such as the central part of Saudi Arabia. The problems here appear to be typical of those of many parts of the arid land countries. Saudi Arabia, as many other developing countries, is only making progress on the national task of constructing good large scale maps. Some of the work has been completed during the last few years, but the attention here has been only paid to those parts scheduled for immediate development. Thus the rest of the country is only covered by generalized small scale maps such as the geographical and geological maps of 1:500,000. Under such circumstances, and due to the availability of aerial photographs, morphological mapping from these photographs/

photographs is the only alternative left to any geomorphologist, geologist, or geographer working in this part of Saudi Arabia.

Aerial photographs are also of importance as they can give an overall idea of the general appearance and characteristics of the landforms. Thus they could be used to plan more detailed fieldwork from the office. Furthermore, they enable many features that are not shown or could not be drawn on topographical maps to be recognised easily even though they are not available in maps.

If stereoscopic pairs of photographs are available as well as some suitable instruments for measuring parallax values, then these photographs can be used to obtain the heights and the slopes of the desired landform unit and/or facet.

The photographs, by showing much larger areas than can be appreciated from the ground, are the best companion in the field in the absence of adequate maps. They can also allow one to map in the office, with limited effort and minimum costs, a much larger area in a shorter period than would be needed by other methods of mapping. It should be repeated here that the photographs are the best method to use to obtain the necessary information in many fields of investigation where there are no other equivalent source materials available.

Although not all geomorphological problems can be solved by using aerial photographs, (such problems as dynamic or morphogenetic), they can be used successfully for mapping the landform units, and the interpretation based on such method provides an objective description of the arid landforms.

The major steps which have been taken towards mapping and aerial photographic/

photographic interpretation of the landform units of the area of our concern are in the following order:

a) constructing the draft base maps from aerial photographs and photomosaics was carried out by using the Hilger & Watts Stereosketch. The instrument consists of a stereoscope mounted on a stand which incorporates an adjustable drawing board. This allows variations of scales between the aerial photographs and the base map to be accommodated, and further permits some adjustment for tilt and scale differences among the photographs, so reducing plotting errors. The distance from the drawing board to the eyes can also be varied by using the supplied lenses under the binocular head. Plotting of details can be done directly from aerial photographs onto prepared or existing maps without correcting accurately the height distortion by using some other elaborate plotting instrument. The Stereosketch is not however a photogrammetric plotting instrument and its use in this instance is qualified by the ability to plot interpretation detail on to controlled mosaics used as base maps.

b) Field check of the draft maps where in doubt of distance, size, and shape by using surveying equipment.

c) Completion of the maps and the final drawing with the aid of aerial photographic interpretation.

The determination and the selection of symbols in relation to the features desired and the size of the map is one of many problems associated with morphological mapping. If the nature of the morphological map is that/

that it must have a functional purpose, then another problem of representation should be added to what is already mentioned. In most recent morphological mapping the aim is to produce a purely scientific map which is easily readable by geomorphologists, but very difficult to interpret by other earth scientists such as engineers, and hydrologists. And since the aim is to provide a functional map, it must, eventually, be readable by those who might use it, other than geomorphologists. But to fulfil this task, the problem becomes very complicated. The use of symbols, the amount of information which should be presented in the map, and the cartography of the compiler are some of the problems which arise when attempting to produce a functional morphological map.

Wind action forms such as sand sheets, sand drifts, free moving sands, and the mobile dunes are much easier than other features to recognize and map. These features are very common in the arid land topography. The gravel plains are also of different kinds; should such difference be necessarily shown in the morphological map? Gravel plains are particularly important in exploration because there might be hidden under the cover of gravel some interesting geological formations. The stony gravel plains might also protect the finer materials to be blown away by wind.

Water action produces forms and deposits which provide large amounts of information about the processes operating on the particular landscape. The relationship between valley or wadi size and the present seasonal courses is of vital importance in this respect.

The main problem, however, is slope presentation in a morphological map./

map. Slopes can be considered either as dependent or independent landforms. If we are to consider describing the form characteristics in terms of slope morphology and/or morphometry, then the slopes are considered here as dependent forms. But when reasoning that different parts of the slope profiles have been successively developed as elements of larger landform units - so that it is possible to recognize the mesoforms and to reconstruct their morphological evolution -, then the slopes are considered here as independent forms.

Primarily, the problem of symbols has to be solved. Symbols have always been the matter of individual taste. But in recent years the attempt has been made to standardize as many symbols as possible. The problem again is which one to follow? All of them have advantages and disadvantages. This problem as well as some others connected with morphological mapping is discussed in detail in Appendix A.

To conclude this part on mapping from aerial photographs, another system is worthwhile referring to because of its relation to the landform classification discussed in this thesis. The Land System Survey has been designed to yield the maximum of basic information on the physical features of a region from the minimum of fieldwork extrapolated with the aid of aerial photographs. Its functional aim is to produce a composite report on the basis of geomorphological, pedological, and vegetational investigations together with a report summarising this information. The maps are designed to show the landform units or the natural units in its existing pattern for the purpose of regional development planning. The method, which depends mainly/

mainly on aerial photo-interpretation, could be successfully applied in areas where the regional development planning is very urgent (e.g. under-developed arid or semi-arid countries), considering the question of time and cost. It may also be useful in large parts of the humid tropics as well as the developed higher latitude countries.

Hence, it follows that the aim is to represent the landforms assemblage from the stand point of the morphographical dynamics. It should be noted here that such maps must inform of the distribution of the landforms and the relation between landforms whose appearance, dimension, and probable origin and/or history are known. Such maps should, therefore, include all the necessary morphographic, morphometric, morphogenetic, and morphochronologic data. But since this goal is beyond the scope of the information gathered and the time available for this work, it has been suggested that the morphographic and morphometric data would be the subject of the maps with the exception of one or two places where more detailed work had been carried out in the field.

Once the description of the landforms has been established, the next step is to look into some units in more detail so as to investigate the problem of their definition which leads to the question of origin and the processes that have operated on them. The factors involved in determining some of the landform developments are to an extent interlinked and, therefore, much more difficult than it has been appreciated. Nevertheless, in order to study the development of a landform unit the attention should be focussed on the major factors such as rock breakdown - including erosion and weathering,/

weathering, transportation, and deposition.

The grain-size distribution of the aggregated material of a landform unit is the most important property of such sediment in relation to the physical forces which have been acting during transportation and deposition. The properties of a component grain are its size, shape, surface texture, and mineral composition. Grain size is very important because it reveals certain information, whether directly or indirectly, about the processes through which this particular product has passed. The size, for instance, is usually related to the medium of transportation and its velocity. The shape is partly related to the medium of transportation and partly to the distance of transport. The surface texture may reflect some of the subsequent changes due to solution or it could lead to the estimation of the method of transportation.

The main task is to determine the sizes and the shape of the sediment particles in order to relate and compare these properties of clastic sediments with the property of a morphological unit, and to obtain some information about the processes that are involved in forming such forms in the area of study.

In order to avoid over-generalization and meaningless conclusions about the inter-relationship between landforms and processes, it is the general trend in most recent morphological investigation to provide some data about the physical property of sediments composing the landform. This attempt is a step towards explaining the formation of a unit such as a fan or a pediment in terms of the process that appeared to have operated on that unit.

To/

To achieve the above goal, samples were taken from selected units and prepared for size and shape analysis in the field and in the laboratory. In the field by means of direct measurements for the large particles, and in the laboratory by means of sieving, pipette, and microscopic analysis. The sampling technique and the laboratory procedure for this analysis will be discussed in chapter 4 as an introduction to the sediment analysis for alluvial fans and pediments (Appendix B discusses the theory of sieving and sedimentation).

Since the sample may be defined as an aggregate of elements of which the population is composed, the first step towards the estimation of the population parameters is that the elements should be classified so that the population may be identified subsequently. Element classification could be described by two measures; the size and the shape. The population therefore can be characterized by the kind and proportion of its elements. The second step is to provide a set of suitable procedures for specification of each property of these elements which should, consequently, lead to a set of measurements. The interpretation of these measurements will certainly yield a unique description of the sample. This description should in fact be able to be applied to the population provided that the samples have been chosen randomly.

It could be argued, accordingly, that size and shape analysis of sediments will, at least, serve two purposes; a) as the basis for interpreting the manner in which the population was formed; b) as the basis for a comparison between two or more samples.

Applying/

Applying the techniques of sieving and settling velocity, to determine the grain-sizes of clastic sediments, even though it produces some difficult problems, seems to have the advantages and disadvantages of both methods. Measurements, however, obtained by such combined technique are a function of three variables; composition, size and shape.

Finally, it should be stated here that the general purpose of this work is to give some morphological accounts of arid lands in regional fashion. The purpose is to describe the landforms (mapping), to classify them, and to provide some more information concerning some of the landforms and their relation to the process that have been operating on them.

This is, surely, a first step towards more future work in the field of geomorphology through regional investigation in this part of the world. Since this will be about the first attempt in the area, an incredible amount of work has to be done before any prediction and conclusion could be drawn and, therefore, a single effort only adds very little to what is needed. My hope is that the attention should be paid fully to this part of the world where many academic problems in arid land geomorphology might be answered.

PART ONE : GEOMORPHOLOGICAL MAPPING AND LANDFORM CLASSIFICATION

CHAPTER 1 : GEOLOGY AND PHYSIOGRAPHY

GEOLOGY AND PHYSIOGRAPHY

Geology and physiography of Saudi Arabia

Saudi Arabia is a Kingdom occupying about three quarters of the Arabian Peninsula which extends from the east coast of the Red Sea to the west coast of the Arabian Gulf (the Persian Gulf) and the Gulf of Oman. The northern boundary of the Peninsula is Iraq, Syria, and Jordan while its southern limit is the coast of the Arabian Sea. One million and four hundred and eighty thousand square kilometres (927,000 square miles) of the total area of the Arabian Peninsula is occupied by the five major provinces of Saudi Arabia. These provinces are: Al Ḥijāz, 'Asīr, Al Moqaṭa'at As Shamaliyah (the northern province), Najed and Al Ḥassā (see Fig. 1).

The Saudi Arabian desert extends from 16°N to 31°N, and occupies a position between tropical and temperate latitudes. The southern part is much like the Sahara except for the high elevations in the south-west, where there is a summer season for rainfall. Most of the south-west highlands are semi-arid. The northern part has some Mediterranean influence with winter precipitation. The rest of Saudi Arabia, including the study area, is either arid or extremely arid and has no marked season for rainfall (fig. 2). The mean temperatures for the coldest month in Saudi Arabia (except the northern parts where the range is 0°C to 10°C) range between 10°C and 20°C. The warmest month has a mean temperature range between 20°C and 30°C except the northern parts (10°C to 20°C) and the eastern and the Rub'Al-Khali areas (more than 30°C), (see Meigs, 1953).

The/

The western highland reaches an altitude of about three thousand metres in 'Asīr but only fifteen hundred metres in the northern Ḥijāz (9000 - 4500 feet). The Najed mountain belt has an elevation up to one thousand metres (about 3280 feet) dropping gradually to the east coast.

Najed

The central part of Saudi Arabia is a moderate to high plateau of various sedimentary outcrops. This part is locally known as Najed which is the Arabic word for a plateau or a high desert plain. It is that part of Saudi Arabia which lies between Al Ḥijāz and 'Asīr in the west and Al Ḥassā in the east and extends from Al Moqaṭa'at As Shamaliyah (the Northern Province) in the north to Ar Rub'Al Khalī in the south (see Fig. 1).

The geologists of the Arabian American Oil Company (ARAMCO) together with the geologists of the United States Geological Survey (USGS) have divided Saudi Arabia into twenty-one quadrangles (see Fig. 3). The central part of Saudi Arabia or Najed as it will be called, hence and thereafter, is represented by the four quadrangles: Wadi Ar Rummah, Southern Najed, Northern Ṭuwayq, and Southern Ṭuwayq.

Physiography of Saudi Arabia

Saudi Arabia can be divided into eight physiographic provinces which more or less illustrate the outcrop pattern of the geology of Saudi Arabia. These provinces are:

1. The Western Coastal Region

Along the east coast of the Red Sea a narrow low elevated coast plain

(not/

(not wider than 50 kilometres) extends from the Gulf of Akaba in the north to Jayzān in the south (Fig. 6).

2. The Western Highlands

The highlands are a high elevated mountain range as much as three thousand metres elevation in the south. The region is an outcrop of the Basement Complex which is part of the Afro-Arabian Shield separated from Africa by the Red Sea Rift (Fig. 6).

3. The Central Plateau

East of the highlands an extension of the Basement Complex with more recent volcanic flows (Ḥarrah) form a moderate to high plateau with elevation ranging from eight hundred to eighteen hundred metres (Fig. 6).

4. & 5. Najed Plateau and Ṭuwayq̣ escarpments

East of the Central Plateau is a series of west facing escarpments which slope gently to the east and have elevations ranging from five hundred to one thousand metres. The highest part is the Ṭuwayq̣ Mountain Belt which forms an arcuate cuesta extending from the great Nafūd (An Nufūd) in the north to Ar Rub'Al Khalī in the south (Fig. 6).

6. An Nufūd and Ar Rub'Al Khalī

An Nufūd is the northern great sand area where the dunes are very high especially in the western and southern margins. The largest sand body is Ar Rub'Al Khalī which covers more than five hundred thousand square kilometres. It also contains very large dune ridges which reach about 200 metres (Fig. 6).

7./

7. Ad Dahnā' and As Ṣummān Plateau

Ad Dahnā' is the great sand strip east of the escarpment region extending from An Nufūd in the north to Ar Rub'Al Khalī in the south. The average width of the sand strip is fifty kilometres over a distance of about fifteen hundred kilometres with a range of elevation from three hundred to four hundred and fifty metres.

East of Ad Dahnā' is a Tertiary limestone plateau which declines gradually eastwards merging into gravel plains with an average height of three hundred metres in the west to about two hundred metres in the east (Fig. 6).

8. The Eastern Coastal Region

Along the Arabian Gulf (the Persian Gulf) are low rolling sand ridges covered with hummocky sand and sabkhas having a range of width from twenty-five to more than one hundred kilometres (Fig. 6).

Geology of Saudi Arabia

Saudi Arabia can be divided into two major geological units: the Arabian Shield and the Arabian Shelf which in turn can be divided into the following structural provinces: The Arabian Shield, The Northern Ḥijāz Platform, The Interior Homocline, The Marginal and doubtful Areas, Al Ḥassā Structural Terrace, and Ar Rub'Al Khalī Basin (see Fig. 7).

The Shield is mostly Precambrian Basement Complex with more recent (Miocene) volcanic flows (Ḥarrah) scattered throughout the area. The segment is part of the Afro-Arabian dome or shield which was separated by the Red Sea Rift. The Arabian segment extends from the Red Sea (long. 36° E./

36° E.) to the centre of Saudi Arabia at its widest outcrop (long. 45° 40' E.) covering about forty-two percent of the total area of Saudi Arabia (see Fig. 8).

The shelf area consists of exposed sedimentary rocks (Lower Permian to Pliocene), occupying about twenty-one percent of the total area of Saudi Arabia (320,000 square kilometres). The outcrop stratigraphically lies between Cambrian (probably Lower Permian) Sag sandstone and the Tertiary Kharj formation (Pliocene). This great belt of the cyclic sedimentation, being an interior homocline, is the result of the advance and retreat of the Tethys Sea which covered much of the Arabian interior many times during its history. This belief is supported by the fact that the sequence of the outcrops of the Arabian Shelf consists of several marine and non-marine deposits (see Fig. 8).

The rest of the country is covered by Quaternary gravel and silt and the great sand areas. For the detailed study of the Saudi Arabian geology I would refer the reader to the work of R. Karpoff, (1957a, 1957b, 1957c, 1958, 1960), Brown et al, (1960), Powers et al, (1966), Thralls et al, (1956) and P. Lamar (1936).

The Geology and physiography of the study area

The area of Study

Between the north part of Southern Ṭuwayq quadrangle and the south part of Northern Ṭuwayq quadrangle lies an interesting cross section showing the contact between the igneous and metamorphic segment and the sedimentary outcrops on the one hand and the succession of the cyclic sedimentation/

sedimentation outcrops on the other hand. The area extends from Al'Amār in the south west (lat. 23°N. and long. 45°E.) to Khashm Qraydān in the north east (lat. 24° 45'N. and long. 46°E.) occupying more than six thousand square kilometres (2700^2 miles). The area extends from one hundred and twenty five kilometres long to about fifty kilometres wide (78 miles long by 34.5 miles wide). The north-eastern corner of the area (Khashm Qraydān) extends parallel to Ar Riyad - Makkah (Mecca) road about twenty five kilometres north-west of Durmā (see Figs. 4, 5).

The Shield area

The exposed basic and intrusive rocks are similar to those of the other parts of the Arabian Shield in which they consist of belts of the Pre-Cambrian granitic and/or dioritic rocks, sericite and chlorite schist which includes minor beds of marble and quartzite, and some amphibolite schist. In fact most of the area between Al'Amār and Al Quway'iyah is part of the eastern segment of the Arabian Shield. Here are found the igneous and metamorphic rocks which occupy about six hundred and seventy square kilometres of the total area (about 9.7%) (see fig. 8).

The Shield segment mostly consists of alkaline granites, diorites, quartzites, and schists. Different types of igneous rocks are similar to those that have been found associated with gneissic belts which were described by Brown (see Brown, et al., 1960, pp. 71 - 72).

The extrusive rocks are generally andesite accompanied by tuffs, breccias, and conglomerates. The metamorphosed sedimentary materials include different types of schist, mica-schist, talcschist, amphibolite schist/

schist, quartzite, and conglomerate (see figs 12b and 13b).

While the granitic complexes are rich in microgranites, aplites, quartzites and diorites, they are rare in the gabbros and serpentines. The group referred by the U.S.G.S. (1953-1963) maps (I-212A and I-207A), as Andesite and Fine-grained Dioritic rocks, Flows, and Intrusives, occupies large parts of the exposed Basement Complex in the study area. The group includes interbedded phyllite, quartzite, graywacke, conglomerate, and marble. The intrusive phase is according to Brown (1960) represented by epidiorite, diabase, gabbro, and serpentine in thick sills and dikes (the group is shown in figs 12b and 13b). A small proportion of the amphibolite schist, which occurs with massive undifferentiated intrusive and extrusive rocks, appears in the south-east (fig. 12b). However, the larger segment of the amphibolite schist includes graphitic schist, marble, slate, quartzite, jaspilite, conglomerate, and interbedded greenstone derived from the basalt. The greenstones include metadiorite metagabbro, and amphibolite which contain subordinate beds of siliceous slate (see fig. 12b). The sericite and choiorite schist segment includes minor lenses of quartz and marble.

The andesite, the fine-grained dioritic rocks, the flows, and the intrusive rocks are the most common exposures within the Shield segment in the area. They form hills which are from Al Quway'iyah to Al'Amar. It appears north of Muhayriqah, east of Jaddālah, and south of Quday'ān. The apatite, the magnetite and/or the ilmenite are the common accessories of this group. It also contains calcic plagioclase, labradorite, and clinopyroxene with or without orthopyroxene (Figs. 12b, 13b, and table 1).

The/

The dioritic and related rocks are the least common in the area. They are only exposed along the south-eastern edge of Jebāl Khuff north-east of Al Quway'iyah. They contain epidiorite, occasionally normal diorite, diabase, gabbro, and serpentinite and they might represent a phase of intrusion between the granite group and the andesite group (Figs. 12b, 13b, and table 1).

The granite is generally red or pink accompanied by some layered intrusive rocks in many places. They are the second largest group of the Shield segment in the area. The group covers the whole area between Jaddālah and Qufarah Al Mi'zal (Miz'il) in the north and Umm Ad Dabāh in the south (Figs. 12b and 13b).

Karpoff (1957a, 1957b, 1957c), and Brown et al., (1960) have published a correlation of the Pre-Cambrian rocks in Saudi Arabia and the area can be related to this because it is beyond the theme of this work to deal with correlation.

The plutonic rocks which consist of alkaline granites, diorite and related rocks, and pre-alkaline granite are accompanied here and there with some layered intrusive rocks. They are separated in places by belts of sedimentary and ancient volcanic rocks, where in the latter case they are commonly associated with the andesite series.

There are two types of plutonic rocks. In the first place there are the calc-alkaline granite, batholiths, and some rocks with both concordant and discordant features. Secondly, the smaller outcrop is comprised of fine-grained diorite with slate, greywacke, quartzite, conglomerate, and jaspolites./

jaspolites.

The ramped and dissected plateau of the Precambrian rocks slopes east and north from a maximum height of 900 meters near Al'Mār. Brown (1960) stated that "along the eastern edge of the crystalline rocks the permian Khuff limestone transgresses older sandstones on either flank and onto the basement, the contact preserving a profile of a desert pediplain with inselbergs similar to the old surface, but more deeply weathered", (p.154). Some interesting features of the granitic rocks, which appear here and there, form inselbergs and, in other places, ridges while the rest of the exposure has been deeply weathered to desert plains. They have also formed an elevated and tilted pediplain sloping east and northeastwards around Ququday'ān (fig. 12a). This part covers about fifty square kilometres of these pediplains where they are interrupted here and there by scattered deeply weathered residuals (Plate 2).

The bedded rocks of the Shield segment are characterized by the major disconformity which shows a lack of parallelism between the contiguous strata and the plutonic rocks where it is visible. They are generally rich in conglomerate among younger rocks, in tuffs and pyroclastic material among the lava outflows, and in chlorite, sericitic talc and muscovite among metamorphic rocks. The younger metamorphic rocks consist of arkoses, shale, slate, tuffaceous wacke, conglomerate, sandstone and limestone which has been found in some places folded and cut by porphyritic sills and dikes of andesite.

The folds are of the common shape all over the Shield area which are: the simple shape; asymmetrical folds, and plunging folds. They are illustrated south and east of Al Quay'iyah and south of Quday'ān. There are some folded lava structures in these places as well.

Finally, the faults of the Najed Wrench fault zone are low angle normal faults and have a major trend to a northwesterly direction. Nevertheless, despite/

despite this general trend there are local variations (fig. 12b).

The Sedimentary Outcrops

Most of the area from Al Quway'iyah in the south-west to Khashm Qraydān in the north-east (fig. 5) consists of exposed sedimentary rocks which are parts of the sedimentary outcrop of the Arabian Shelf. The exposed rocks occupy more than 100 kilometres long and about 47 kilometres wide of the total area. This part of the Shelf outcrop lies, stratigraphically, between the Upper Jurassic Limestone of the Tuwayq Mountain in the north-east and the Permian Khuff Limestone in the south-west (see figs. 13b, 14b and 15b).

This area as well as most of the Arabian Shelf, forms what is known as the Interior Homocline which is Palaeozoic, Mesozoic and Miocene.

At the lower part of Wadī Al Quway'iyah and along the eastern segment of the Shield the Khuff limestone crops out in the north-west direction. East of the Khuff outcrop and between Al Quway'iyah and Dalqān a large basin of the Quaternary Gravel crops out in about 14 km. wide following the same direction as the Khuff formation and as the rest of the sedimentary outcrop in central part of Saudi Arabia. East and south-east of Nafūd As Sir - the Quaternary sand dunes - the Sudair Shale crops out in small portion at Khashm Dalqān. To the east and north-east of Dalqān and Lughdān, the Jilh formation exposed in the north-west/south-east direction for about 20.1 km. wide. Between the eastern edge of Jillat Al'Ishār (Middle Triassic) and the western edge of Nafūd Qunayfidhah lies the Minjur sandstone outcrop (Upper Triassic to Lower Jurassic). Nafūd Qunayfidhah, the largest sand basin in the area, covers the whole part between Tabrāk in the south and Safrā'Al Ghuzayz in the north. Over scattered areas along the north and west sides of Nafūd/

Nafūd Qunayfidhah the Lower Jurassic Marrāt Formation appears at Safrā'Al Ghuzayz, Safrā'Al Mīrkah, Khashm Zāhim, and Khashm ad Dhuwaybān. The area between Safrā' Al Ghuzayz and the north-eastern edge of the area, near Duramā is covered by unconsolidated superficial deposits of the Quaternary at Khabrā'Al Hawar. In the middle of Khabrā'Al Hawar, just to the north of Al Nuqay'ah (fig. 5) a longitudinal arm of the Upper Jurassic of the Tuwayq Mountain Limestone is exposed between Khashm Qraydān in the north-west and Khashm Mijharah in the south-east following north-west/south-east direction. The whole area forms a very gentle high desert pediplain with some west-facing scarpments at Al Quway'iyah, Safrā'Al Ghuzaya, Safrā'Al Mīrakah, and Khashm Qraydān. The dip of the pediplain is at an average of about 2 metres per 40 kilometres with general direction of east-northeast (fig. 9).

Structure

Most of the eastern edge of the Arabian Shield is overlain by the Permian Khuff Limestone, and where the contact between these sedimentary rocks and the Pre-Cambrian Basement Complex occurs, the Precambrian surfaces are preserved. These surfaces, according to Brown (1960), are part of Najd pediplain. He noted that "there is evidence that at least portions of it are a Precambrian surface buried and exhumed with some modification since exhumation", (p.153). In fact, slight movement is apparent in the Saq sandstone, but there is no evidence of movement beneath the Permian Khuff limestone.

The Palaeozoic, Mesozoic and Eocene belt (known as the Interior Homocline) is a series of west facing escarpments dipping gently to the east with an average gradient of about one in forty. Although this might suggest unusual stability/

stability, some structural interruptions do occur in many places. This stability, however, could be explained as a result of the fact that certain blocks of different sizes and shapes have undergone independent movement without actually disturbing the adjacent parts of the homocline surface (figs. 14a and 14b).

At Safrā'Al Ghuzayz the northern portion of the eastern grabens appear as an elongated flat-topped limestone ridge with an average elevation of about one hundred metres. This rift is dropped beside the uppermost beds of the Marrāt formation showing several hundred metres of displacement. The flank of the Marrāt block ends with a segment of overlapping fans which covers the fault margin of the graben in places with some low passes which appear to be synclinal sags, which break through the limestone ridge which forms the exposed part of the graben (fig. 15b).

The southern portion appears at Khashm Zaḥim (lat. 24° 33'N. and long. 46°E.) which is part of the Awsāt graben where it appears as a deep trough just over Marrāt surface. According to Powers, et al., 1966, the grabens could have been formed by a high-angle fault with drag folds and auxiliary faults (p. D108).

Stratigraphy

The Khuff Formation: At the lower part of Wadī Al Quway'iyah, as well as the eastern edge of the Arabian Shield, the Permian Khuff Limestone is exposed in the north-west/south-east direction. This formation was named, dated/

dated, and formally designated by Max Steineke and Others (1958) as a type section of Permian Limestone at 'Ayn Khuff latitude 24° 55'N. and longitude 44° 43'E.

The outcrop of the Khuff Formation in the area ranges between 80 kilometres long and 25 kilometres wide. The formation generally consists of dolomite, shale, and limestone. The dolomite and shale beds with subordinate fine-grained limestone including thin layers of granitic sand and fine conglomerate, is between 35 - 40 metres thick in places. The limestone with prominent layers of fine-grained limestone is between 65 - 74 metres thick. Finally, the limestone with calcarenitic limestone which have beds of 25 - 30 metres thick bring the total thickness of the Khuff formation to 155 - 178 metres (see fig. 13b). Bramkamp et al., (1958) measured total thickness of the Khuff formation near Ar Rayn at locality 23° 32' 45" - 23° 43' 00"N. and 45° 34' 30" - 45° 42' 00"E (see also tables 2, 3, and figs. 8 and 12b).

The limestone of the Khuff formation is generally light coloured interbedded by argillaceous limestone, dolomite, marl, and gypsiferous clay. Different colour of the sandstone/shale unit is usually found at the base of the formation (Figs. 8, 13b, and tables 2, 3 and 4).

<u>The Sudair Shale</u>: The occurrence of the Sudair Shale in the area is only in small isolated remnants of the formation and crops out in a very thin band between Khashm Dalqān (latitude 24° 15' 31"N. and longitude 45° 30' 58"E.) and Khashm Lughdān (latitude 24° 17' 24"N. and longitude 45° 35' 56"E.) just to the east part of the south tip of Nafūd As Sir (Figs. 7, 10). The type locality/

locality section of the Sudair Shale at Khashm Ghudayy and Khashm Ramadah, Al' Ārid scarpment, was considered as a formation by Steineke and Bramkamp in 1952.

The Sudair Shale was dated as upper to lower Triassic shale. The exposed part in the area occupies about 15 kilometres long by less than 2 kilometres wide. There were no measurements carried out in the small portion of the Sudair Shale in the area, but in other localities its thickness has been measured between 198 metres as a maximum and 161 metres as a minimum (see tables 2, 3, and fig. 13b).

The series of the Sudair Shale are, mainly, shale-brick to dark-red massive shale with occasional siltstone (figs. 9 and 10). The shale is interbedded in a complex manner with, light-gray, strongly platy, slightly micaceous, and calcareous siltstone, and off-white, argillaceous and silt, limestone. The contact is conformably overlain by the adjacent Jilh formation, and the outcrop of the Shale covered by the Quaternary sands of Nafūd As Sir from the west (see also tables 2, 3, figs. 9, 10).

<u>The Jilh Formation</u>

Jillat Al' Ishar: The formation is exposed continuously between Dalqān, Lughdān, and Nafūd As Sir in the west and Jabāl Ubayd and Khashm Al Midyā'ah in the east (fig. 5). The total outcrop covers about 450^2 kilometres of the area. The formation was examined at Khashm Musayqirah (latitude 24° 18' 45"N., longitude 45° 41' 10"E.).

The Jilh formation was dated as Middle to Upper Triassic Sandstone and Shale Unit. It was formally considered as a formation by Steineke in 1958 at/

at the type section at (latitude 24° 03' 48"N. to 24° 11' 06"N.) and (long. 45° 46' 00"E. to 45° 51' 30"E). The outcrop consists of buff to massive and coarse-grained sandstone interbedded with green, purple, and red siltstone and shale with a few thin beds of limestone in places. The upper beds are arenaceous oolite and oolitic sandstone with thin layers of platy black and brown ironstone abundant in the upper part.

At Khashm Muṣayqirah limestone and subordinate dolomite and shale appear with several anhydrite members in the upper part. Table 5 summarizes the lithology and the thickness of the formation is shown in figure 10.

The Minjur Sandstone: This formation crops out over an area measuring about 60 kilometres long and about 25 kilometres wide following the north-west/south-east direction. It has been examined at Tabrāk (latitude 24° 21' 36"N. and longitude 45° 54' 15"E.).

The Minjur Sandstone in Saudi Arabia extends, as Powers, et al., (1966, p. D-37) stated, from the eastern edge of the dip slope of Jilh formation up to the base of Marrāt formation in the face of Khashm Al Khaltā (or Khashm Al Minjur). The width of the outcrop as he measured was some 33 kilometres across at its widest point at latitude 24° 30' N. (fig. 5).

The upper Triassic sandstone and shale of the Minjur formation was classified as the upper member of As Sir group, but it was later in 1951 when it was formally recognized as a formation by Gierbort and Bramkamp. The formation was in the list of Steineke paper about the stratigraphic relations in 1958.

The sandstone is buff, massive, usually crossbedded with irregularly distributed/

distributed varicoloured shale, sandy shale, and shaly sandstone. Some minor beds of ironstone appear in several places. The formation generally consists of light coloured, fine to coarse-grained, sandstone with varicoloured shale, and in many places some conglomeratic materials occur in various layers. The thickness ranges between 315 metres at Khashm Al Minjur, 290 metres at Khashm Adh Dhibī, and 185 metres north of Wadi Ar Rimmah (see tables 2, 3, Figs. 9, 10, and 14b).

The Marrāt Formation: Lower Jurassic Limestone (Toarcian), shale, and sandstone. The formation crops out in the area at Khashm Qraydān latitude 24° 45' N. and disappear under the Quaternary gravel then expose again at Safrā' Al Ghuzayz latitude 24° 38' 42" N. and at Safrā' Al Mirakah latitude 24° 35' N. Another portion of the formation crops out at Khashm Zaḥim latitude 24° 32' N. and at Khashm Ad Dhuwaybān latitude 24° 28' 45" N. (see Figs. 9, 10).

Powers (1962) has sampled and measured the Marrāt formation where they have considered a reference section at Khashm Adh Dhibi. Powers, et al., (1966) published a detailed description of this section. A summary of lithology and the thickness of the formation is given in table 6. Moreover, the formation generally consists of golden-brown to tan limestone and dolomite with middle member of dark brick-red silty shale and thin sandstone beds of lower Jurassic age (Toarcian age). The total thickness of Marrāt formation varies between 120 metres at Khashm Qarayдān and 137.8 metres at Khashm Adh Dhibi (Figs. 9, 10, 14b, and tables 2 and 3).

The/

The Durumā Formation

Middle Jurassic Limestone, shale, and/or sandstone crops out in very small patches along the eastern edge of Safrā' Al Mirakah. But this formation is exposed over a distance of more than 900 kilometres of the Arabian Shelf. Its outcrop covers about 25 kilometres wide between the Quaternary sands and gravels in the west and the Ṭuwayq Mountain outcrop in the east (Figs. 9, 10).

The formation consists of tan limestone with interbedded brown calcarenite, partly oolitic, with some olive-drap clay shale on top. The thickness measured by Powers, et. al., (1966) east of Khashm Adh Dhibī is 374.5 metres. Tables 2 and 3 represents a generalized summary of the lithology and the thickness of the formation is also shown in figure 10 and table 7.

The Tuwayq Mountain Limestone: The formation is Upper Jurassic Limestone, and is exposed only, in the area, at the north-eastern corner between Khashm Qraydān in the north-west and Khashm Mijharah in the south-east. The limestone is an isolated arm of a huge, and most impressive, formational outcrop in central Saudi Arabia. The formation is 1200 kilometres long forming a very long arcuate cuesta. The lithologic continuity of the formation shows much more fascinating features of the geomorphology and the geology of Arabia (see Figs. 9, 10).

The Ṭuwayq contains, generally, cream and white, massive, compact limestone including basal marly unit and, locally, few thin layers of calcarenitic limestone. The aphanitic limestone is about 29.8 metres near Khashm Qaraydān, and the aphanitic-calcarenitic limestone is 45.2 metres thick

(see/

(see also tables 2, 3, figs. 9, 10 and 15b).

<u>The Quaternary Gravel</u>: Part of the sedimentary outcrop in the Shelf area is covered by Quaternary gravel. This part lies between Al Quway'iyah and the Khuff formation in the south and Nafūd As Sir in the west. About 650 square kilometres of the area is covered by the lower to middle Quaternary gravel. The deposition is a sheetlike lag of gravel and consists of quartz and other sorts of pebbles from the Basement Complex (fig. 13b).

<u>The Quaternary Silt and Gravel</u>: At Khabrā Al Hawar (fig. 15b) middle to upper Quaternary unconsolidated surficial deposits of silt, sand, and gravel crops out between The Safrā areas in the south and the edge of the study area in the north. The deposits include undefined quantities of other units of the Quaternary age (fig. 15b). The gravel and silts are also found in the thick layers covering pediments and in alluvial fan beds. This suggests some relation between those forms during the Quaternary era. This also indicates that there have been two phases of very wet periods during the Quaternary period namely the middle and the lower Quaternary (between C and B, P.I-166). Furthermore, the association between the gravel lag formation and pediment and fan formation supports the argument, presented later, that these forms have undergone several phases of arid and semi-arid periods during the Quaternary.

<u>The Eolian Sands</u>: Recent sand dunes and sheets cover two major parts in the area;

1. The west part or Nafūd As Sir occupies about 230 square kilometres between the Gravel in the south-west and the Sudair Shale in the north/

north-east.

2. The east part or Nafūd Qunafidhah which covers about 650 square kilometres lies between the Minjur Sandstone in the south-west and Safrā'Al Ghuzayz and Safrā'Al Mirakah in the north-east (figs. 9, 10 and 11).

Both sand accumulations referred to cover the lower areas and lie parallel with the sedimentary escarpments. In most areas the dunes appear to cover the gravel plains. According to Brown (1960) at least parts of the gravel plains seem to be Quaternary. He also noted that the nafūds are developed on and near the granite patholiths, which are exposed when the larger Wadis (such as Wadi Ar Rimah) have removed part of the crystalline Najd, where the grus has been transported both by the Wadis and the wind (Brown, 1960, p.157). Holm (1953) has also pointed out that the nafūd As Sir forms a projection of sands from the large mass of sands accumulated along and within the course of Wadi Ar Rimah.

The Physiography of Najed Plateau

Between Jebāl Khuff in the south-west and the Tuwayq mountains in the north-east some high desert plains of low relief of limestone, shale and sandstone, outcrops over more than three quarters of the area. The Najed pediplains, or the high desert plains, are relatively elevated areas of comparatively flat land which is commonly limited on at least one side by an abrupt descent to lower land. The most impressive parts of this type of physiography appear at small outcrop of Sudair shale, at Khashm Dalqān and Khashm Lughdān, and of the Jilh formation at Khashm Musayqirah. The Jilh sandstone and shale unit form a landscape of low multiple benches with persistent regional strike of N28^{o}W. The area is mostly covered by Permian and Triassic sandstone, shale, and limestone. The sedimentary succession of Central Saudi Arabia including the study/

study area has developed since the beginning of the Cambrian era, dating different phases of the advance and retreat of the Tethys sea (Powers, et al 1966).

To the east and the north-east of the Shield segment, and to the north of Nafūd Qunayfidhah some series of moderately low, west facing cliffs of arcuate shape, of limestone and sandstone origin crops out in two major parts; one in the south-west part and known as Jebāl Khuff, and the other between Safrā'Al Ghuzayz/Al Mirakah and Alnuq'ah.

The north-eastern part including some parts of Marrāt formation and the Tuwayq limestone appears to be the most impressive physiographic unit in the area. The topographically low relief between the huge arcuate escarpments of the Tuwayq Mountain and Safrā'Al Guzayz/Al Mirakah might indicate a retreat of the west face of the large arcuate belt of the Tuqayq to the east leaving some longitudinal arms of the outcrop.

The landscape of the study area has been developed to its recent shape by the gradual formation of the gravel plains and the sand dunes during the Quaternary era. The sands cover two parts: Nafūd As Sir and Nafūd Qunafidhah. The general direction of the sand dunes is north-west/south-east with one or two exceptions where the sand basins follow a general direction of west/east. Those basins might have been some Sebkha basins in the wetter period, filled with undulating rolling sands during the recent dry period.

PART ONE : GEOMORPHOLOGICAL MAPPING AND LANDFORM CLASSIFICATION

CHAPTER 2 : GEOMORPHOLOGICAL MAPPING

GEOMORPHOLOGICAL MAPPING

Principles and Methods

Definition, Concept and Purpose (see also Appendix A)

Definition: Aerial photographic interpretation is the study of aerial photographs in order to define, analyse, classify and evaluate the images of objects that can be seen on the photographs relating to a particular field of investigation. By definition, aerial photographic interpretation is a method that can be used widely in the field of geomorphology. Geomorphological mapping and landform classification and mapping are good examples of the application of aerial photographic interpretation in geomorphology.

The method can be used as a starting point in any geomorphological mapping procedure that involves time and cost limits. It is of great value in the geomorphological mapping of areas that lack much of the necessary information and which pose problems for ground survey. Such problems include size and accessibility. The interpretation of photographic coverage of such an area as the study area, (including the use of ground controlled mosaics) provides an outline of the recognizable geomorphological features which can be rapidly mapped even without a visit to the field. But after collecting all available sources of information, the outline base map can then be tested against field information. Thus, the major features of the landforms are subdivided and more features can be added to the map. Following a short visit to the field, most of the geomorphological features can/

can then be identified, analysed, finalised and compiled in much less time than is required for ground surveying. Although considerable space was devoted in the introduction to the problem of mapping, it nevertheless appears necessary, here, to consider again the various problems related to the production of the maps presented.

Concept and purpose: The subject of geomorphological mapping is the surface of the study area with its all morphological characteristics. The mapping has been used as a method to define, identify, outline, and later, classify the landforms as parts of a system (or systems) of surface forms. The geomorphological maps here deal with the appearance of the landforms qualitatively and quantitatively. Thus, the geomorphological maps show forms occurring in the study area, in relation to their genesis and spatial relationship, analysed and mapped for the purpose of storing qualitative and quantitative information for scientific and/or practical purposes. However, reliable results can only be obtained if the work is carried out with care and expertise and if a field check is included in the programme. Further detail concerning the concept and purposes of geomorphological maps have been discussed in Appendix A, which deals with the development of geomorphological mapping. One can only hope that such geomorphological enquiry is a successful attempt that can lead to further development in geomorphological mapping in this part of the world and it can be a useful representation of the landforms, that will be used as a guide to other workers in other fields.

Mapping problems

It has been stated (Appendix A) that geomorphological mapping has developed very rapidly during the last thirty years. It has also been stated/

stated that such developments have been concentrated in areas (or countries) where much of the necessary topographic, geologic, and pedologic maps were available in those parts of the world (see Appendix A). It should be stated here that, for geomorphological mapping of an area such as the study area, the circumstances are different. Good quality, large scale, topographic and pedologic maps are not available. Thus the compilation of the geomorphological maps has been a laborious, expensive, and time consuming task. The field visit has to be longer than it is needed for similar geomorphological mapping programme that are carried out with sufficient information at hand. Another problem related to the above mentioned problems is the size of the study area. To handle such area as the study area is a time consuming job. But on the other hand the ground survey method would have involved much greater time and cost than what has been spent. A further problem was that such a programme, in order to be comparable to other systems (ITC System or IGU System), discussed in Appendix A, would need a team of specialists from different fields. It also needed a large supply of equipment in addition to transportation so that the programme would bridge the gap caused by the lack of information and base maps.

Classification and systematization of the landforms for detailed mapping creates additional problems to the map scale and the definition and identification of the landforms. This problem, however, is discussed in chapter 3.

The map scale is a central problem in any geomorphological mapping.

What/

What the map should include or exclude is a problem of scale. If the scale is small, more important features have to be generalized or even excluded from the map. On the other hand, if the scale is very large the spatial relationships between the major features has to be sacrificed, because individual map sheets can cover only a relatively small area. However, once the scale has been decided upon, the problem of selecting the more important landforms to be shown in the map has to be solved. even at the expense of generalizing or excluding other forms. A decision has to be taken concerning the purpose of the map if possible. If not, then a series of maps instead of one for each area is likely the alternative so that the maps would represent the desired characteristics. The scope or the purposes of the map are of great and prime importance since such maps are to be used as scientific documents. Another point that should be considered is the concept of distribution; such as the distribution and the spatial relation of forms whose origin and age should be determined in order to recognize and appreciate the geomorphological development of the mapped area.

Scale also affects the amount of detail that is cartographically possible to present in the maps in relation to symbol sizes and number, and also the number of shadings that are possible. However, the location and the distribution of the landforms have been determined by their defined appearance, their defined origin, and the scale of the maps. Slope has been broadly subdivided because of map scale. The problem of showing the slope categories together with the landform unit boundary especially in/

in massive denudational landforms (see figs. 12a and 12b) is very difficult to achieve cartographically. The result is the compilation of two basic geomorphological maps for each area with overlays, so that the areal distribution of landform units could be shown together with individual morphological features. Comparison of figure 12a to 15b indicates the difficulty (if not impossibility) of producing each set of maps as a single sheet. Slopes themselves could be defined morphologically (such as straight, convex, and concave slope), morphometrically (such as slope angles), morphogenetically (with regard to the processes operating on the slopes), or morphochronologically (by estimating the ages of the slopes). The choice is obviously very difficult. Here again the scale of the maps and their purposes are decisive factors. The choice followed was that which allowed morphological and morphometrical information to be presented.

However, the choice of scale for the geomorphological maps as well as the cartographic ability of representing the geomorphological phenomena in certain size and arrangement are beyond any doubt major issues in geomorphological mapping. They are also important factors in mapping the landforms for classification purposes. Nevertheless, this issue is further discussed in Chapter 3, which deals with landform classification.

The source of information and mapping procedure

Information sources: The initial sources for the geomorphological maps are; standard vertical (9" x 9") aerial photographs (scale between 1:35,000 and 1:60,000); controlled photo-mosaics (scale 1:50,000); geological and topographical maps (scale 1:50,000 without contour lines); and some literature. Photographic interpretation is, therefore, the major source. As indicated earlier the original field programme was to sample representative landform units for/

for quantitative analysis that could be used in the mapping procedure. Because the field programme was interrupted and the time was not enough, sampling was sufficient only for two units (pediments and fans). However, some samples were obtained from other units as well. These samples were analysed and their general granulometric classifications were used in the morpho-lithological maps. Such information is shown between brackets in the legends of figures 12b, 13b, 14b and 15b. A summary of the mean percentages of gravel, sand and silt fractions of the above mentioned samples is given below:

No. of total samples	Morpho-Lithological Units	Mean % Gravel	Mean % Sand	Mean % Silt
9	Wadi beds	15.69	49.38	2.91
16	Alluvial accumulation terraces	2.88	65.93	31.19
30	Bahada	27.28	52.93	19.79
10	Fluvial erosion terraces	43.52	42.43	None
55	Pediments	29.92	51.42	18.66
15	Gravel plains	47.22	34.95	3.63

As shown in this summary the differences between the general modes of the samples mean sizes of pediments and fans is small. This has supported the idea of further analysis of the sediments of these two units (part II).

Mapping procedure: The technique carried out consists of the preliminary construction/

construction of an outline map on a medium scale (1:50,000), which is also the scale of the controlled photo mosaics used as base maps here, of a rectangular plan (15' latitudinal axis and 30' longitudinal axis) for each part of the study area. The outline maps are mainly photographic interpretations of the major features of the landforms. This was done on a Stereosketch machine by transferring detail from stereo-pairs on to each controlled photo mosaic sheet covering the whole rectangular plan.

The outline maps, when completed, were then checked against the available geomorphological and geological information. This led to the search for more information to fill in the gap produced by the difficulty of definition and identification. Therefore, the maps were carried to the field where a major ground testing and checking was done. This also led to further analytical studies in the field and later in the laboratory. The next task was to draw a semi-final map for each area (again at the medium scale 1:50,000 stated above) that would include all the morphologic, morphometric, morphogenetic, and other information collected from the field and laboratory analysis. The final task was then the completion of the drafts of the semi-detailed geomorphological maps with the aid of further aerial photographic interpretation. Throughout the mapping procedure, cartographic advice and help has to be consulted.

Since the semi-detailed geomorphological maps were to be finally prepared and completed in a special black and white format, it became apparent that it was cartographically impossible to present all the information needed (and collected for this and other purposes) in one sheet./

sheet. It was very difficult, if not impossible, to contrast the shadings of the morpho-lithological units with those of the morphological features areal distribution let alone adding the individual morphological feature's to this complex.

The alternative was to produce the semi-detailed geomorphological maps in the following format:

a - Morphological maps (figs. 12a, 13a, 14a and 15a);

(A) Morphological features (shown as overlays),

(B) Morphological areas (landform types) which are the base maps.

b - Morpho-lithological maps (figs. 12b, 13b, 14b and 15b);

(A) Morphological features (as overlays),

(B) Lithology and chronology shown as base maps.

Each map of the above set of maps (including overlays) is designed either to be used as a special purpose map by itself or in combination as required for different means and purposes.

The Geomorphological Maps

Legend and presentation of the maps

The legend: The range of symbols used in the semi-detailed geomorphological maps has been determined by the scale of the preliminary maps, the type of the area worked in (arid and semi-arid landforms), and the purpose of the maps. In such parts as the study area there is a very clear and sharp distinction between the denudational forms and the depositional features.

This/

This is shown by drawing the boundaries of the denudational forms on both the base map and its overlay (compare figs. 12a and 13a with their overlays). This distinction has also been emphasised by drawing solid lines for boundaries of denudational forms and broken lines for depositional forms and/or by different line thickness according to the cartographic situation (compare figs. 14a and 14b with 12a and 13a). Surface deposits and/or lithology of both maps have also distinct shadings. Denudational forms are either shaded with solid lines (except those forms which either consist of broken features such as inselbergs and other residual hills - see fig. 12a), or conventional symbols are used (such as granite symbols - see figs. 12b and 13b and for regs and ergs (see figs. 14a and 15a)).

In the shield segment of the basement complex (figs. 12a and 13a) there are distinct features of the arid uplands that are not very significant in other climatic zones. The most important of these features in this case are the breaks of slopes on hill-crests or hill-sides. These features are the results of the relative resistance between rock materials (such as dykes) to erosion and weathering. The breaks of slopes are shown together with their values in degrees with conventional symbols (see figs. 12a, 13a, 14a and 15a).

Wind action forms (such as sand sheets and dunes, gravel plains, depressions, etc.) are also marked features of the arid and semi-arid landforms. Thus, they are distinguished by broken lines and conventional shadings (see figs. 13a, 14a and 15a). Sand sheets, sand ridges, blow-out hollows,/

hollows, dome shaped and barchan dunes, longitudinal and transverse dunes, and gravel plains have been shown by different shadings.

Although most of the streams are occasional, the water action, even in the driest parts, has left impressive marks over a large part of the landscape. Water courses are shown by broken lines on the overlays as individual features (see overlays for figs. 12a, 13a, 14a, and 15a). On the base maps (figs. 12a, 13a, 14a and 15a) the relation between valley sizes and the present flow rates can be established by comparing the stream bed areas with the water courses on the overlays.

Terraces, such as fluvial erosion terraces and alluvial accumulation terraces are shown in both base maps (figs. 12a and 12b, 13a and 13b, 14a and 14b, and 15a and 15b). This is because they are morphological units as well as morpho-lithological units combined with morphochronological units (compare the terraces in figs. 12a and 13a with those in figs. 12b and 13b). Some of the erosional terraces are associated with basin areas which have probably been excavated following recent uplift marked by the faults shown in figures 12a and 13a. While other erosional terraces are associated with the development of inselbergs.

Since the structure plays an important role in this part of Central Saudi Arabia (see chapter 1), it was necessary to show some structural features in the maps. They are individual features (such as fault lines and fault line scarps) and therefore they are shown in the overlays (see particularly figs. 12a, 13a, and 15a overlays). Other individual features such as summits and crest lines are also shown in these overlays (see overlays for figs. 12a and 13a).

Furthermore,/

Furthermore, important landform units such as alluvial fans, pediments, cuestas, tablelands, ergs, regs and hamadas, in addition to their representation as morpho-lithological units, are shown (by shading and different line thickness) as geomorphological units which have special characteristics in terms of their genesis and areal distribution (compare these units as they are shown in figs. 12a, 13a, 14a and 15a with the units in figs. 12b, 13b, 14b and 15b).

On the semi-detailed geomorphological maps (figs. 12a to 15b) not only major morphogenetic relief types have been shown, but also individual slopes of the larger valleys and divides (see figs. 12a and 13a). The slopes, here, are shown as part of the relief types as well as independent relief elements. The maps only distinguish between horizontal and sloping surface and between denudational and structural slopes (see figs. 12a, 13a, 14a and 15a).

Although the maps have emphasized the predominance of the exogenous elements of the relief they also include some of the endogenous elements such as fault line scarps (see overlays for figs. 12a and 13a). However, depending on thephysiographic conditions and the scale of the maps, the relations between the main morphological areas and superimposed morphological features of the relief types have been emphasized whenever possible.

When denudation has operated for long period over a relatively stable landsurface, the morphology is often characterized by the development of broad removal surfaces separating zones of dissected relief. Such features form important groupings (landform systems) within the geomorphic landscape. They are referred to where appropriate (see hamadas, fig. 18, and System IIH, fig. 18 and tables 9 and 10). Thus a comparison between a number of the relief-forming processes acting as individuals and/or combined agents have been considered/

considered so that the maps would reflect the role of such agents and the resultant landforms.

The maps have also been designed to include the geology of the area units and their broad chronology. They emphasize the composition of the deposition as well as the lithology of the denudation relief. Other geological information such as stratigraphy, structure and sedimentation are discussed in the text and have not been included in the morphological map legends (see chapter 1).

Finally, the maps are not detailed geomorphological maps of the type produced by some European countries (see Appendix A), but they are geomorphological documents designed to give as much information as possible. However, it should be emphasized here that the geomorphology of the study area has not been fully explored and this work is the first systematic work of its kind. Thus, the expectation of many gaps to be filled is great. Some of these gaps are in the fields of Quaternary chronology, dynamics and endogenetics. The hope lies in future work which would enable the development of detailed geomorphological maps of this part of Saudi Arabia as well as other parts of the country. Until such work is done these maps could be used as base maps for more detailed and special purpose mapping programme. The maps, however, can also provide sufficient information for application in the field of underground hydrology and other assessments (for further details see Appendix A, p. I-210.

Presentation

The/

The landforms of the study area have been divided into the following groups occupying the base of the morphological maps (figs. 12a, 13a, 14a and 15a):

(a) Denudational landforms which include features such as ridges, residual hills, inselbergs, cuestas and tablelands) that have been eroded in solid rocks into dissected regions such as uplands and mountain ranges;

(b) Fluvio-denudational landforms that have been created by denudational mass movements and/or sheet wash and other fluvial agents (such forms include pediments and erosional terraces);

(c) Fluvial depositional landforms that have been developed by the activity of running water such as wadi beds, alluvial accumulation terraces, and alluvial fans, and

(d) Eolian landforms which have been developed by wind action such as sand dunes, sand sheets, and blow-out hollows.

Individual landform features such as breaks of slope, water courses, fault lines, crest lines, summits, and fault line scarps are presented in separate sheets (overlays for figs. 12a, 13a, 14a, 15a, and underlays for figs. 12b, 13b, 14b and 15b).

The morpho-lithological units have been presented in separate sheets (figs. 12b, 13b, 14b and 15b) in the following manner according to the categories above:

(a) denudational units that include the denudational landforms as distributed in lithological-geological areal distribution,

(b) fluvio-denudational units which are the same as those in figures 12a, 13a,/

13a, 14a and 15a,

(c) alluvial units that include certain lithological information, and

(d) eolian units which in addition to the morphological units include features such as ergs, regs and hamadas.

Abbreviated chronological data are presented in the morpho-lithological maps (figs.12a, 13a, 14a and 15a). The abbreviation used has been derived from the geological maps and modified to denote the geological period and epoch.

Interpretation and the need for landform classification

Interpretation: For any practical purpose, it has been argued that the maps of the landforms should be relatively easy to read, interpret, and apply; that such maps must provide short but expressive identifications to satisfy the requirements of simplicity and allow small areas to be properly mapped, and that the maps should include enough information concerning an area to allow some evaluation of the geomorphological characteristics of that area qualitatively and quantitatively. Such maps should produce areal units that can also be evaluated for assessments and other practical purposes. The geomorphological maps of the study area do not satisfy these requirements. They are difficult to read for non-specialists, require skill to interpret, and perhaps may not be easy to apply. The reason is that such maps have been designed to give sufficient information about the geomorphology of the study area to those who are very much interested in such information. The maps include details that are necessary/

necessary for other practical fields so that they need a specialist to read and interpret. Contrary to other landform maps the legend of the geomorphological maps is concerned with the characterization of the morphogenesis, morphology and sedimentation of the study area. That is to say that the maps provide much more information than needed for many practical purposes. The maps are also concerned with the morphochronological data that are needed for the evaluation of the development of the landforms in time. This is another fact that serves the special purpose of these maps rather than other practical purposes. The essential reason for the development of the geomorphological maps of the study area is, however, that the landforms are characterized by different environments. The effect of such factors as rock types, tectonic movements, type of processes, topographic positions, profile developments, and other geological factors causes internal and external modifications that caused significant differences in the morphological characteristics of these landforms. It is very clear that the geomorphological maps will not facilitate the practical usage of the maps by non-specialist. However, such difficulties can be largely overcome by other methods of mapping such as the landform classification method.

<u>The need for the landform classification method</u>: It has been stated earlier in this chapter that the first step in outlining the geomorphological maps was the recognition, identification, and mapping the major landform systems or units. This facilitates the idea of using the Land System Classification method for landform classification and mapping. A method that/

that has been successfully used by other workers (see chapter 3) in the field of applied geomorphology. This method is discussed in the following chapter and has been made the basis of summary maps (figs. 16 - 20 and tables 9 - 11) which are derived from the geomorphological maps of the study area (figs. 12a - 15b).

PART ONE : GEOMORPHOLOGICAL MAPPING AND LANDFORM CLASSIFICATION

CHAPTER 3 : LANDFORM CLASSIFICATION

LANDFORM CLASSIFICATION

Land evaluation, land classification and the land system approach

Interest in the uses of the land, both actual and potential, characterize the work of several groups and organizations. Among these are: the Division of Land Research and Regional Survey of the Commonwealth, Scientific and Industrial Research Organization of Australia (C.S.I.R.O.), the Land Resources Division of the Directorate of Overseas Surveys (DOS), the Military Engineering Experimental Establishment (MEXE) and the joint group known as MEXE-OXFORD GROUP (see Beckett & Webster, 1965a).

The attempt to classify the land (land classification, including land evaluation) was made to establish scientific research and to develop techniques that bridge the gap between methods of detailed field analysis and methods of reconnaissance in order to meet the requirements of the land utilization and/or planning programmes launched for immediate development.

The term land classification is used to identify and record the land (for definition of land, see Christian and Stewart 1968, Mabbutt 1968) characteristics which are of potential significance to man such as: landforms, soil, vegetation and water and to map the area of occurrence. Hence the land system approach is to classify the information obtained about a particular area and to store and/or use this information for evaluation.

The mapping unit of the C.S.I.R.O. is the land system which is an area with a recurring pattern of landforms, soils and vegetation, mappable from aerial photographs. The role of geomorphology in providing the physical basis/

basis for land system mapping is evident throughout the reports of the C.S.I.R.O., the DOS and the MEXE-OXFORD groups. It appears to be that the basis for land system mapping is the pattern of the landscape which is made up of groupings of the landforms, soils and vegetation. If this is the case then in arid lands, where vegetation is scarce and the soil is poorly developed, the land classification based on landform and sometimes soil patterns should be regarded as comparable to those of the tropics (which include vegetation). It follows that the landform classification would provide adequate information for integrated surveys of the desert terrain aiming at practical application. Since the main grouping of the land system here will be the physiographic or the geomorphic units, it has been designed to take into consideration the scheme of the joint group (MEXE-OXFORD) and the Cambridge Study group for desert land classification (see Hughes, et al., 1965, Perrin, et al., 1969).

The need for classification here is to illustrate the relationship between different landforms in the study area. One should admit, however, that even when attempting a land evaluation scheme it requires a team of scientists rather than one geomorphologist. It should be noted here that the landform classification for the study area is presented for the special purpose rather than the general purpose (which is practical). Nevertheless, the scheme could be used for more practical programmes as the necessary preliminary information. One could add that the question of landform classification arises when dealing with morphological mapping from aerial photographs.

It could be argued that if the regional development should include

rapid/

rapid geomorphological analysis of the elements of the whole region (playing an important role in its development) then the use of aerial photographs should be included, whenever possible, in any mapping procedure designed for such purposes. This is because of many factors (mentioned before) involved in minimizing and economizing the efforts towards regional development.

Landform classification

Dividing the landforms into units has been the concern of several authors (see Bourne 1931, Hudson 1936, Linton 1951, Clark 1957, Lueder 1959, Beckett and Webster 1965, Hughes, et al., 1965, Savigear 1965, Mitchell, et al., 1966, Perrin, et al., 1969a, Thomas 1969, Young 1969, and Mitchell 1971). Although most authors claim a practical definition and hierarchical ability of their classification, the problem remains controversial. In fact, there are three major factors contributing a great deal to the controversy. These factors are:

1. The validity of the conclusions derived from small areas concerning larger regions, provinces and zones in terms of prediction, uniformity, similarity and differentiation.
2. The validity and the existence of the units in nature according to their defined boundaries.
3. The scale in which the defined units are mappable with minimum costs to fulfill the map content and its use for other purposes.

The unit to be accepted is an area where the climate, landforms, soil and vegetation lie within the limits significant for a particular form of land/

land use, and should be sufficiently uniform in its physical property to enable a farmer to manage the whole extent of one facet in the same way (Beckett and Webster 1965, see also Gibbons, et al. 1964). The complexity of the land and its gradational properties have been simplified. This is because the classification of the landforms is always subjective and boundaries have to be drawn somewhere. However, the landform classification is less complicated and more applicable than the land evaluation which involves other factors such as soil and vegetation.

It could be argued that the landform classification is a systematic arrangement of different kinds of landforms according to those properties that determine their size, shape and texture in order to establish similarities and differences. Therefore, it should provide the preliminary boundaries for those more extensive units which include other factors in order to determine the land capability for permanent sustained production.

If the <u>site</u> (Linton 1951), the <u>unit landform</u> (Lueder 1957), the <u>morphological unit</u> (Savigear 1965), the <u>land element</u> (Brink, et al. 1966) or the <u>relief unit</u> (Young 1969) indicate certain uniformity among the small scale landforms, the major landform units vary even within one area to such an extent that no strict rules can be applied (see Linton 1951, p. 215, and Thomas 1969, p. 115).

In dealing with landform classification it is not always so easy to formulate an hierarchy of the landform units. This is because of the complexity and the nature of certain types of landforms. It is as Thomas (1969) pointed out "certain landforms occur more often as complexes than as simple/

simple units.....", an example of these landform complexes is "... a two (or more) cycle-river valley ...". In fact, it could be argued that a pediment or a bahada with its size and sometimes indefinite boundaries and surface texture cannot be regarded as a simple mappable landform unit because a bahada for example is in itself a combination of smaller units and a pediment might be glacis or structural form. First because of the scale problem and second because it would not be manageable in the same way as the simple unit. It is, therefore, more acceptable to use the term <u>landform complex</u> which was introduced by Thomas (1969, pp. 118-119) for those units which have a more complicated nature (see chs. 5 and 6).

It should be added here that the landform complexes (or the landform complex types as it would be used in the landform classification of some parts of Central Saudi Arabia) could be used to indicate those landforms which are comparable in the way that;

a) - they should have been developed during the same period of time,

b) - they should have morphological similarity, and

c) - they might have a similar genesis and

d) - a similar constituent material.

Therefore, these units should be distinguished on the strength of morphological consideration and not on the basis of topography, lithology combined together. This is because a landform complex may be the result of the operation of two or more climatic sequences acting on a particular lithology during a period in which that particular form or forms has been developing.

The scale problem

It is obvious that the smaller the scale of the units to be mapped the greater the number of forms has to be generalized (or vice versa). It follows that the map's content is dependant on the scale to a large extent. The scale is also important for the purpose of the map in terms of the degree of precision needed in the map. For regional purposes, for example, a scale between 1:250,000 and 1:50,000 is sufficient for indicating the general direction of development. But when the need is for detailed information in terms of land capability the upper limit of the scale becomes inadequate. Furthermore, using the upper limit it is very difficult, in practice, to show every potential unit specially when size and shape plays an important role. The problem of classification within the above mentioned scale limits is which class of the landform should be within the upper limit and which one falls into the lower limit.

If the aim is to classify the landforms in terms of their morphogenetic elements, then the complicated nature of such forms would result in a great variety and number of morphogenetic combinations, so that when represented it has to be generalized with either different or combined forms.

In spite of all the difficulties, the medium scale (1:250,000 - 1:50,000) is sufficient to show the major mappable units (see tables 9 - 11) of the desert landform. This is only applicable when the preliminary work has been done on the scale 1:50,000 to 1:80,000. Then the final map could be reduced to the desired scale. For our purpose the range of scale between 1:250,000 for landform systems and 1:100,000 for the landform complex types seems/

seems to be reasonable. It must be considered here that the availability of material has so far determined the scale (these are; aerial photographs at scale approximately 1:60,000, photo mosaics at scale 1:50,000 and geological and topographical maps at scale 1:500,000).

It could be argued that although the smaller scale maps are more readily appreciated in handling, it is more practical to produce these maps on a medium scale. It is because such maps would be used for more detailed work and by other interested groups in planning and development (e.g. for underground water). Future work, however, should bridge this gap in terms of maps for general, applied and special purposes.

Landform Classification for the Study Area

Hughes and others (1965) have classified the terrain in an evaluation scheme where they include examples from various parts of the arid lands. Mitchell and Perrin (1967) subdivided the deserts of the world into physiographic units. Perrin and Mitchell (1969a), attempted "to evaluate the extent to which a new physiographic classification of landscape can be used as the basis for the storage of practical information about terrain from which predictions can be made about conditions at unvisited sites", (p. 1). Mitchell (1971) claims that in testing the "practical value of facets by assessing their internal homogeneity and mutual distinctiveness over this whole climatic zone...", the facets were found "adequately homogeneous and mutually distinct to be useful units for sorting scientific and land-use data within single land systems..." (p. 69). But he also found that "over wider expanses of territory..." the value of the facets "diminished/

"diminished to unacceptably low levels for most purposes" (p. 69). In applying this system for the landform classification of the study area it has been found that although it could be applied anywhere in arid lands it has to be modified according to the local variation, complexity and scale.

The classification of the landforms for the study area has been developed as a result of the aerial photographic interpretation and the morphological mapping which is the subject of the previous chapter. It seems that the most valuable method of identifying landform units and for classifying them is the use of aerial photographic interpretation. This is not only because such a technique reveals more information about the land surface (such as micro-relief, drainage pattern, etc.), but also because it shows clearly the relationship between all facets involved in designating the landscape. As a result a visual comparison (which will lead later to detailed analysis) between the units can be made.

It should be noted here that when classifying the landforms one should pay careful attention to the micro-relief and the morphologically discordant lines. These lines have been delineated on aerial photographs first and identified and named later by a synthesis of morphological characteristics. This should be the case when it was stated that 'a landform unit is the result of the operation of climate upon a particular lithology in which such forms have been developed'.

If we accept the argument which defines the smallest mapping unit as the genetically homogeneous surface which is geometrically a simple area which does not contain any breaks of slope, then we would exclude some parts of the arid lands where some of the elements are not simple. It has been argued/

argued that even the genotically homogeneous surface, no matter how simple or complicated, is the result of complex processes acting in certain directions. It follows that by a landform complex type we delineate a complex of forms in a more or less distinctly limited area. Unlike other units it is not a concrete unit but an abstract unit established in a deductive way. Accordingly, this type of landform may be divided into two groups according to their inclination. The first group are the highly inclined surfaces and the second are the flat surfaces.

It has been found more practical and convenient to set up the morphological regions first and complete the geomorphological maps, then work out the subdivision of these regions from larger to smaller units with the aid of the semi-detailed geomorphological maps and field work. The degree of the division of these units will depend upon the degree of the relief development. It is always easier to determine the accumulation surfaces (which are mostly the simple units) than to group the erosion-denudation surfaces (which are mostly the complex units).

The maps shown in figures 12b, 13b, 14b, 15b and 16-20 have been constructed according to the foregoing concepts and compiled from aerial photographs and the morphological maps. They should, therefore, reflect the existing units of the landforms in the area.

Procedure

The study area is divided into three major regions; the southwestern region, the central region and the northeastern region (see Table 9). Each region is subdivided into landform systems and each system is further subdivided/

subdivided into landform types; (see tables 10 and 11) complex and/or simple. These types are then divided (mapped only in a sample area, fig. 20) into some groups of the same lithological and morphological criteria (for detail of this classification see figs. 16 to 20). The morphological criteria are based on the slope classes as boundaries between facets.

When the morphological maps were reduced to publication scale (1:100,000 approx.) the classified units were delineated into a framework and also reduced to its presentation scale (1:100,000). This scale imposed certain modifications to the original scheme devised by Perrin and Mitchell (1969) of the physiographic units of the desert landscape. It also takes into consideration suggestions made by Lueder (1959), and Thomas (1969). The C.S.I.R.O. classification has two major subdivisions; the land system, and the land unit, and the MEXE-OXFORD report has three subdivisions related to medium and large scale maps: land system, land facet, and land element. The scheme adopted here consists of three major subdivisions:

(a) <u>landform system</u> (IA, IB, IIA, etc.), (b) <u>landform type</u> (t), and (c) <u>landform type unit</u> (tu).

The landform types are of two categories:

(1) <u>complex type</u> (ct), and (2) <u>simple type</u> (st).

The landform type unit is also of two categories:

(1) <u>complex type units</u> (ctu), and (2) <u>simple type units</u> (stu).

The hierarchy of this classification could be summarized in the following manner:

Landform/

Landform System

Landform type

Simple — Complex

simple landform type units* — complex landform type units

The classification together with the morphological characteristics of the landform systems, landform types, and landform type units are shown in figures 16 to 20 and tables 9 to 11.

The mapping scale for the landform systems and the landform types is approximately 1:100,000. This scale is related to the complex unit landform of Lueder (1951, see also Thomas, 1969, table 6.1, p. 116). Although the scale of the landform types also corresponds to the land units of C.S.I.R.O. (see Christian and Stewart, 1953; Christian 1957), they are only morphological and physiographical units. The simple landform type units here, however, correspond to the facets of Beckett and Webster (1965). The mapping scale of the sample area is approximately 1:35,000 (see fig. 20 and table 11).

Information concerning the geomorphological characteristics of the landform types and the landform units has been initially obtained from photographic interpretation. Sampling the units was not sufficient to perform tests on the practical value of units, their homogeneity, and the degrees of difference and similarity between the landform units. Therefore, prediction about unknown areas from known areas could not be achieved. However, Mitchell (1971) has pointed out that predictions concerning unknown areas can be achieved without visiting the sites. He considered the occurrence of a facet within a whole climatic zone/

* equivalent to the land facet (Beckett and Webster 1965).

zone as well as within land system local forms. His conclusion which states that "prediction does increase with the limitation of the geographic area considered", (Mitchell, 1971, p.77), is very interesting. It is important to be able to recognize a facet and predict its properties with sufficient accuracy, so that a facet can be distinguished from others within a landform (or land) system, a region, or a province from aerial photographs only, thus reducing the cost and time needed for long field trips. Unfortunately, there are no representative data sets from the study area or elsewhere in Saudi Arabia available at the moment for testing the homogeneity or variability among facets. This kind of investigation is left for future work to be carried out in the study area or in any part of Saudi Arabia.

The map legend and presentation

The landform types and the landform type unit maps are areal summaries of the morphological characteristics of the classified landforms. Because of the scale problem only the landform types are shown (figs. 16 - 19), but a sample area containing the major landform type units within combined landform types (IA, ID and IIE; see fig. 17), is shown on a large scale map (fig. 20). This has been done in order to demonstrate the relationship between landform types and the landform type units. It is in fact to illustrate the complexity of the landform and to some degree serve to give the necessary information for assessment planning.

It has been argued that individual landforms such as summits, crest lines, fault lines, and water courses are morphological (linear) features and cannot be considered as mappable (areal) units. Thus, these features are excluded from/

from the landform classification maps. Conversely, at the scale 1:100,000 (which is approximately the scale of figs. 16 - 19), it is impossible to show smaller units without changing the scale. (This scale has been selected so that the areal units should correspond to those of the geomorphological maps. Compare figs. 12 'ab' with 16, 13 'ab' with 17, 14 'ab' with 18, and 15 'ab' with 19).

The landform systems (corresponds to the morpho-lithological units) are shown in the maps by thick lines (see figs. 16 - 19 and tables 9 - 10). The landform types are, however, the major features of figures 16 to 19. Thus figures 16 to 19 would be read as a major land system (e.g. IA, IIC, IIB, etc.) which consists of numbers of landform types; complex and simple (e.g., IA consists of ct_1, st_2, etc.). The landform type units are shown in separate sheets for reasons discussed elsewhere (see fig. 20).

The maps for the landform types and the landform type units have been designed to be simple to read and interpret, and serve as a summary for the semi-detailed geomorphological maps. Each map (figs. 16 - 19) represents exactly the same area shown in the geomorphological map sets (figs. 12a - 15b). Thus, a comparison between the two methods is established. But more clearly, the later maps (figs. 16 - 19) will facilitate the practical usage of the maps as well as minimizing the problem of interpretation and/or giving a quick reference to what are the major characteristics of the study area.

The major characteristics of the study area

(I-A) Al'Mār/Umm ad Dabah/At Tayby System: The mappable unit consists of a group/

group formation which includes andesite, diorite and related rocks, and generally somewhat metamorphosed sediments. The system in fact is the reflection of the behaviour of the very slow weathering processes typical of arid conditions. It also shows a clear distinction between the landforms developed in this area and the adjacent systems. The system is shown by its code (I-A) in figure 16, together with the landform types coded as: ct, and st in the same figure.

The distinction of this sytem is even more emphasized by the bare, steep-sided and jagged mountains with scattered small and large basins. But the land surface remains generally well dissected and of strong relief. This system, however, possesses a variety of lithological constituents. Variation even occurs in the same type of rock, while dykes and sills and veins (that can often be easily recognized in other localities) add further complications. Accordingly, the morphological features of the landscape are extremely diversified. Some distinction in the seemingly chaotic landscape of this system may, however, be gained from the landform sculpture. This is the case over the whole crystalline terrain. The landscape here is generally less rugged than the granitic terrain. The hills tend to assume rounded and smooth/

smooth outlines while their slopes are, in places, covered with moderately coarse debris instead of being boulder-clad like granitic mountains. Owing to the extreme variability in rock resistance, the resultant landforms sometimes approach the rugged and craggy appearance of the granitic landforms. The drainage system also reveals variable characteristics. This is foreseeable; where softer rocks prevail the landsurface has been profoundly dissected by river erosion and the valley floors are wider with different range of earthy mounds. Summit level accordance is displayed over large areas. But some, however, rise in a more or less isolated manner above the general surface plain. With the recent processes of denudation on the steep features as well as at the foot of the slope different types can be discerned. In this system fluviatile dissection of the slopes and pediments is prevailing. The active development of a pediment can be observed in some cases. It is suggestive here that younger alluvial fans might bury the relicts of older pediments that are best preserved near the mountain front (south and east Al'Amār. This problem, however, will be discussed in more detail in the following chapters (see tables 10 and 11).

<u>(I-B) Muhayriqush/Jaddalah/Quday'an System</u>: is mainly granite. Owing to its qualities granite everywhere gives a characteristic landform. The granite presence is often heralded by broken blocks of different sizes. The outlines of these blocks is determined in the first place by the prevalent mode of jointing. Exfoliation and the fissuring of the blocks are/

are well developed. The pediments and the pediplain of this system are dotted with blocks of granite and inselbergs which reflect the nature of desert weathering over a very long period. Although these blocks are piled up one above the other, granitic massifs with rounded summits do occur in places (e.g. around Quday'ān). They may be eroded into steep angular forms with serrated crests and ridges, or they may form very steep-sided mountains (e.g. east of Al Quway'iyah).

The drainage system is usually of fine texture and dendritic pattern. The less resistant parts are affected by the occasional development in predominantly granitic terrain of intermountain basins and wide valley tracts. Such plains, dotted here and there with granite knobs and hillocks, occur in the parts extending from Al Quway'iyah southward to Quday'ān. The dominant feature here is a planation surface. This is often dissected so that it has a relative relief of 10 - 100 metres, reflecting differential erosion along bands of lithological weakness. It is further surmounted by some considerable mountain residuals. The pattern of scarps and outcrops south of this area indicates a general uplift along a west-east axis with a strong monoclinal flexure along the southern margin and a gentle plunge at the north. The drainage pattern may also furnish evidence on the nature of the uplift. The drainage directions have three components: first streams draining north; secondly, streams draining south, and thirdly, streams draining to the fault trough. The last two seems to be discordant upon the crystalline rocks and the first is consequent upon the planation surfaces (figs. 13 and 16).

(I-C)/

(I-C) 'Aqabat Al Mishār System: These exposures of the lineated metamorphic rocks are less fully developed than system I-A. They also show a parallelism of features and often display crags and pinnacles and sharp divides. The forms are clearly distinguished by bedding and structural features. The drainage system is mainly controlled by the structural pattern of the area. However, the present relief of this system is probably due to the degree of resistance of rocks of which it is composed. The structural ridges constitute a persistent feature where stratification is pronounced (e.g. east of Al Quway'iyah). The strike of foliation coincides with that of stratification and a steep inclination. The hills of this system, however, are generally more subdued than in other systems.

Normally the system possesses a curved joint unit which reflects the current surface form only in the initial stages of destruction. Whether the residual forms occur singly or in groups they appear unrelated to the regional drainage pattern which is superimposed on their distribution.

(I-D) Khuff System: a profile of limestone escarpments and a desert pediplain deeply weathered and showing the contact between the Permian limestone and the crystalline rocks. Although in many other places the contact is between the older sandstone (namely Saq and Wajid) and the Basement Complex, the sandstone in this area was deposited, according to Brown (1960), in basins 'while the intervening somewhat higher region was bare during a period preceding the deposition of the Khuff' (p. 153). Even under arid or semi-arid conditions the effect of solution is a pronounced relief/

relief striking topography which is, possibly, produced as a result of the enlargement of fissures by percolating water. The deep, very steep sided, valleys occur everywhere along this system where the ground water flows out occasionally. A good example is Wadi Al Qudray'iyah. The surface of the west face of this system is very coarse textured while in some places due to minor irregularities the surface of interfluves is very uneven. Mesas and buttes are common forms where the enlargement of joints or other separation planes in the rock occur.

The striking forms are those beds of limestone overlying the Basement Complex rocks. The exposure, being bare rock and resistant, stands out from the surrounding landscape. The degree of resistance enabled the drainage system to reconstruct most of the main drainage lines of the pre-Permian time. This shows that the modern occasional stream courses follow the older ones to a remarkable extent considering their superimposed nature. It is because of the weakness of the Khuff system compared with underlying Basement Complex, so that once the ancient topography begins to be revealed, the streams tend to migrate laterally against the weaker rocks of the cover. The active development of a pediment could be observed only in a few cases.

The profiles within this system show distinct breaks of slope between the cliff faces and the lower concavities, and the narrow convexity of the upper parts of the slopes is apparent just above most cliff faces. The progressive decrease in particle size downslope indicates diminishing energy. The reduction of energy may be interpreted as being affected by the short occasional heavy rain* over highly permeable surfaces together with high trans-evaporation rate and the change of slope within a short distance.

Convexity/

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* Unfortunately there are no climatic data available at present for this part or any other part of the study area.

Convexity in the lower slope sections is only possible when the climate changes considerably through an extraordinary increase in rainfall or through a rapid incision from considerable uplift. The incision which thus rapidly occurs can produce steep slopes upon which the potential energy in the rainfall is transformed so effectively into kinetic energy that all weathering material aggregating downslope can be taken up and removed in increasing quantities. In this system concavity often continues up to the lower limit of the convex upper slope section. The streem network on the eastern margin of this system emerges from the massif range ends of the marginal uplands and disappears below the sediments of sand and gravel which were formed by the alternate action of wind and water. Tributaries follow the joints in a closely spaced, geometric pattern. All minor valleys are canyons and the valley system partly unrelated to rock structure appears outside the geometric pattern. Their dendritic pattern remains within the crustal cover of the limestone.

As a rule, throughout the eastern face of this system, the slope consists of two distinctly different parts; the upper, nearly vertical, and the lower, inclined and of different lithology. The inclination of the lower part shows an angle of 30 - 40°. In many places where the covering/

covering layer prevents the exposure of the underlying rocks, the knick between the valley side and the wadi floor is very sharply defined. In the areas where sedimentary rocks exhibit steeper inclinations, there is a distinct asymmetry of slope forms. In such cases, one of the slopes is inclined conformably with the dip of the rock strata. While examining the surfaces spreading at the base of the slopes in Wadi Al Quway'iyah, one repeatedly notices an exposed bedrock overlain by thin sheets of loose material. The inclination of these surfaces ranges between 2 and 4° and the thickness of the accumulative cover on the bedrock is between 10 centimetres and one metre. Among the features appearing on slope surfaces (here and in most parts of the second and third regions), there are steps and erosion incisions. The occurrence of steps is caused by exposures of harder rocks (igneous and metamorphic), sheet joints or landslides.

Two features must be regarded here as the most common in all slopes; the bare surface or the absence of unconsolidated material on the slope surfaces and the sharp break of slope between the top and the base (figs. 16, 17 and 20).

<u>(II-E) Al Quway'iyah/Al Hawar Systems:</u> over a large area east of Jibal Khuff (including the lower part of Wadi Al Quway'iyah) and in Al Hawar area (which is part of a large gravel plain south east of Ṭuwayq mountains known as Al Butayn) the processes of deflation cause the removal of the finer material by wind. This action left nearly flat surfaces of gravel (reg) of coarse pebbles and sands composed of more resistant rock. Gravel of this type represents a recent concentration of coarse debris from the immediately/

immediately surrounding area. It also represents a residual deposit derived from older sediment or rock by removal of intergranular fines and a lag concentrate from an earlier gravel sheet. Large areas in these systems have in common a flat, firm surface (which consists of fine sand and silt) that contrasts sharply with other crusty, brine-saturated depressions. One factor involved in the origin of these gravels is that the sediments were deposited by both water action and wind sedimentation. Other factors involved are those suggested by Hövner (1936) and Beaumont (1968). These are the alternate wet and dry conditions of the ground and the high salt concentration in gravels which they believe can play important roles in the breakdown of pebbles into fine fragments. One cannot ignore here the thermal expansion of salts and the crystal growth from solution and hydration of anhydrous salts (see Cooke, et al., 1968 and Strakhov, 1970).

Because of its flat and uniform surface these systems would only have two simple types of landforms according to its lithological differences. These are the gravel surfaces and the silt (figs. 17, 19 and 20).

(II-F) As Sirr/Qunayfidhah Systems: consists mainly of sand dune complexes known as conical sand hills or dome-shaped dunes (see Holm 1953). These hills are dominated by large sand massifs and often with superimposed dune patterns consisting of various types of complex barchans. They are the most characteristic pattern of the sand dunes of Central Saudi Arabia. They form distinct and individual features separated from each other by sand ridges and deflation hollows. The dune diameters range from 500 metres/

metres in As Sirr system to 2,500 metres in Qunayfidhah system. Their height is within the range of 50 - 200 metres. In many places the surface of the dunes is clearly marked by transverse mobile crescentic dune ridges. The ridges are not a simple product of deflation but the result of sedimentation and deflation over the surface of the great dunes. They appear to have an arrangement in parallel rows. These systems, by virtue of the size of huge conical hills, provide considerable resistance to the wind with an accompanying increase in the wind gradient. As a result the wind tends to veer towards the larger dunes and so deposits more sands on and around them.

The development of these dunes is due to certain considerations. These are: the very large area of the source material, the scarcity of the vegetation cover, the vast level expanse of scorching plains and the strong air movement in circulation. It could be stated here that the wind would bite (in addition to other kinds of weathering) deep into the exposed surface and at the same time carry the aggregates further away where they would be heaped up into the form of dunes. But this is the very generalized explanation and for more detailed analysis one should refer to the pioneer work of Bagnold (1941). The dunes then become self-perpetuating because they become sites of rising convection currents. The dune types of the central region (as well as Central Saudi Arabia) are combined into a number of recurring associations. The dome-shaped dunes (which are the large well defined features) are often (in the southern and northern parts of these fields) bounded by sand ridges with an oblique orientation. The ridges/

ridges are almost invariably associated with swarms of low longitudinal features which cut diagonally across the ridges (figs. 18 and 19).

(II-G) Dalqān/Lughdān System: is a series of pediplains of low relief bordering the dune system of As Sirr from the north east. The surface of the shale pediplain is flat and rocky texture with remnant monadnocks. The mixed resistant rocks of this system has developed a pediplain with west facing very low relief scarpments (50 - 100 m. above the ground, e.g. Khashm Dalqān and Khashm Lughdān). In fact, the overlying shale group have evidently been subjected to almost continuous erosion since the beginning of the Triassic era. Consequently, the landforms, either produced by or related to initial structural features, have long since been obliterated by erosion. Such a state is supported by the notion that desert landscapes owe much to the length of the stage of development. The landscape, however, may be the result not only of the varying influence of structure and stage, but also reflect the climatic factors which obviously determine the processes at work (fig. 18).

(II-H) Musayqirah System: is another part, but has higher relief than the pediplain of the central region. The landscape is dominated by a broad belt of multiple benches with a persistent regional strike of N. 29°W. This series of ragged, sand-drifted benches persists south south-westward to a bold scarp whose steplike outer profile reaches a relief of 150 metres at Khashm Musayqirah. The benches continue north-eastward until breached by the wide plain of Tabrāk system. This surface bevelled all but/

but the most resistant rocks and varies from an irregular reg to a hammada (rocky desert) surface covered by desert varnished deposits.

The erosion of the sedimentary cover commenced, leading eventually to the formation of the benches. The dominant general landscape is a pediplain. This is often dissected so that it has a relative relief of 10 - 50 metres reflecting differential erosion along bands of lithological weakness (fig. 18).

<u>(II-I) Tabrāk system</u>: is a sandstone outcrop typically weathered to broad gravel plains with scattered black hills and low discontinuous benches. The relief is somewhat more pronounced toward Khashm adh Dhibi (lat. 24° 13'N.). The overall landscape is a flat stony desert showing the denudational destruction of the former exposed sandstones over a very long period. The climatic phases and the geomorphological processes since the beginning of the Jurassic era have not left any clear climatic/genetic landforms except the erosion surfaces which are the black hills and the benches. This may have been the result of more resistant rocks and perhaps a more semi-arid pediplanation period. But this has no evidence to support it (fig. 18).

In fact the central region has very large areas of sandstones and limestones. The sandstones form plains and the limestones escarpments. The limestone escarpments (which are the west-facing fronts of the benches) are truncated at low angles by the development of desert surfaces and are sloping gently to the sandstone plains. Field observations revealed that the planation surfaces do exist with a deep decay and ferruginous crusts. These/

These old surfaces are formed in the Tertiary sandstone of the continental shelf. At the time of their formation (with the presence of ferruginous crusts) there explained more humid climate in the region at that time. The problem has to be investigated more in the future as to what degree the climatic changes are necessary to effect decisively the morphogenesis of the area.

(III-J) Al Ghuzayz/Al Mirakah system: is a discontinuous exposure of lower Jurassic limestone. From Khashm adh Dhibi the system loses its topographic distinctiveness as it dips under the dune system but it reappears as isolated remnants which can be seen within and along the northern margin of Nafūd Qunayfidhah. This erratic pattern system is at least related to local fractures and flexures displayed from the Central Arabian graben system. The benches become progressively more prominent at Safrā Al Ghuzayz and Safrā Al Mirākah where it forms a pair of steep west-facing cuestas that dominate the surrounding landscape. The upper escarpment is 60 metres high which was formed by erosion of soft red shale under a resistant cap of upper marrāt limestone. The lower scarp is 45 metres high and held up by rough, blocky-weathering, lower marrat formation. The rest of the isolated remnants of Lower Jurassic limestone dips under the protective ledge of the Upper Jurassic limestone (namely Ṭuwayq̣ escarpment), (see fig. 19).

(III-K) Qraydān system: This system is a small proportion of the Ṭuwayq̣ system which dominates the topography of both the central and the north-eastern/

eastern regions. Over most of its extent the limestone of the Upper Jurassic forms a table land with two precipitous outward facing scarps. Differential relief from the top of the scarps to the gravel plain floor is more than 250 metres. The tableland is surrounded from the north and the south sides by pediments. The north side pediment is partly covered with small size barchan dunes which has been drifted from the north margin of Nafūd As Sirr. The top part of the tableland forms a flat surface but highly dissected in many places. The system in fact is preserved as prominent ridge and erosional remnant of the larger province, the Ṭuwayq mountains (fig. 19).

The above mentioned descriptions are only a summary of the geomorphological characteristics of the study area as can be deduced from the maps (figs. 12a - 20). Certain problems, however, such as the interrelationships between the landforms and the processes cannot be fully discussed without further analytical studies. The maps themselves can only give indication to what has happened and what is happening to the landforms. But the stages of development in relation to processes and forms are not contained in the legend of the maps.

It has also been stated before (chapter 2) that during aerial photographic interpretation programme it has been found that some of the landforms were very difficult to identify and/or to define from the photographs. These forms (such as pediments and alluvial fans or bahadas) haveto be looked at in the field.

Considering the importance of these landforms in our understanding of desert/

desert geomorphology, and having being faced with other problems mentioned above, further analytical studies were necessary for the purpose of this work. As stated earlier (chapter 2) the essential difference between the desert landforms and landforms of other climatic zones is the clear and sharp distinction between aggredational landforms and degradational landforms. Thus, it seems justifiable to select one of each of these groups so that the comparison could be established. Among the desert landforms two particular forms has been investigated by several authors. These forms are pediments and alluvial fans. Still disagreements and controversy occurs between those authors about the definition, the development, and role of pediments and alluvial fans in desert geomorphology. These two forms, however, are the subject of the analytical studies of part II of this work.

It has been stated before that the study area was selected because of its accessibility and the availability of information. The area was also chosen because it includes representatives of a large proportion of the different kinds of rock structures and landforms in Saudi Arabia. Therefore, the geomorphologica mapping and classification scheme worked out for the study area should be valid for mapping the whole country.

Having dealt with geomorphological mapping and landform classification in the previous sections, the attention is now concentrated on the identification and analysis of two of the more characteristic (yet problematic) landform units (pediments and fans). A procedure for field work and laboratory analysis is given below. This procedure has been designed for clastic sediment analysis in pediments and fans. By studying the clastic sediment at surface and near surface, an attempt is made to discover the relation between forms and processes at work on these landforms.

PART TWO : THE ANALYSIS OF PEDIMENTS AND FANS

CHAPTER 4 : PROCEDURES FOR PARTICLE SIZE ANALYSIS AND PEBBLE SHAPE

PROCEDURES FOR PARTICLE SIZE ANALYSIS AND PEBBLE SHAPE

Field Procedure

Sampling

The random sample is a sample selected from a population in such a manner that each item in the population has an equal chance of being selected. If this method is applied when sampling from landform units it could only produce certain information about large groups (populations). But when sampling in an analytical survey the objective is to compare different subgroups of the population in order to discover whether differences exist among them that may enable us to form, or to verify, hypotheses about the forces at work in the population.

When dealing with very complicated populations (such as landforms), the sampled population may not coincide with the population about which information is wanted (the target population). Sometimes, for practical and convenience reasons, the sampled population is more restricted than the available population. Since this is the case in most landform populations, it should be indicated that conclusions drawn from the sample apply to the sampled population. The extent to which these conclusions will also apply to the target population must depend on other sources of information.

Axiomatically, if the inductive argument from sample to population is to be justified, the sampling procedure should yield samples which will represent the population one way or another. The requirement of the inductive/

inductive argument is that as the number of items in the sample (n) approaches infinity (N), the sample mean ($\overline{X}$) should become closer to the population mean (U) and, therefore, the sample variance (σ^2) should converge with the population variance (σ).

It is the scope of the following procedure of sampling to calculate (this will be dealt with in its appropriate place) some statistical measures (such as the sample mean $\overline{X}$, the variance σ^2, the standard deviation σ, the skewness SK, and the kurtosis K) to test their fitness and relation in order to estimate, or perhaps to relate to, the population parameters. By this it is hoped to draw some conclusions on the population of the sampled area.

It should be noted here that indicating the problem of sampling and the experimental errors in sampling and laboratory procedures is easier than to attempt to solve them. Under such consideration, and since sampling from the available population is widely common, the conclusions presented in the following chapters have been based on samples derived from the available population in selected stations.

Since it has been generally accepted that each landform unit is in itself a sample of the landform system, and that each land facet or element of a particular landform unit is a separate case of that unit, it should be accepted that a sample from each element is a representation of that element. Assuming that our samples are fairly representative; that is to say that each sample of the land unit or even/

even element is a homogeneous representation, then the results of the experimental work, which has been performed on such samples (which had been derived from small populations to represent larger ones), should be correct. But the fact is that the problem is much more complicated than it sounds and sampling errors involve more than the question of randomness.

The first step, however, is to choose a population from which the samples are to be taken to the laboratory where each one of them is to be subdivided further into specimens by means of a splitting technique. The selection of the specimen had to be based on the assumption that each one is large enough to contain at least most of the grain sizes in the sample (where each sample should be large enough to contain all the size range in the layer or depth and that each one from the same depth is to be confined into a continuous depth line along the traverse).

Although the sampling procedure used in the field has many errors and the samples are derived from the available population, it has been designed to yield some information about the processes involved in the formation of these particular land units or elements in Central Saudi Arabia. The conclusion derived from these samples, therefore, should be considered as an attempt to explain the inter-relationship between these particular forms and the processes operating on them.

<u>Sampling procedure</u>

The sampling procedure was in the following manner: the land systems had been chosen from the central part of Saudi Arabia on the basis/

basis that it consists of the major landform units. The availability of materials (such as maps, geological information, and aerial photographic coverage), the access to the area, and the interesting contact between the Basement Complex and the Sedimentary Outcrop have played an important part in determining the study area. According to the time limit the investigation was mainly concentrated upon two particular landforms; pediments and alluvial fans. Each of these forms has been regarded as a population by itself. Then, and in order to relate the particle sizes to slopes, sites along the profile are determined at a maximum of 250 m. interval between each site on pediments. From each site a surface sample was taken and, then a sample from each of the following depths: 1, 2, 3, and 4 metres was selected. The weight of each sample had to be between ½ and one kilogram because of the problem of sending the samples to Britain. On the alluvial fan, the site intervals were at every 500 m. and the depths were at surface, 2, and 4 metres.

<u>Field procedure</u>

Other field work was done as follows:

1 - 100 pebbles had been selected from each site on pediment A, with a total of 500 pebbles, and another 100 from each site on pediment B, with a total of 600 pebbles, to be measured in the field for gravel analysis.

The measurements for the gravel analysis are: the length, the width, and the thickness. Another dimension is necessary for the determination of the roundness of pebbles. This is the smallest radius of/

of curvature of the least rounded part of the pebble. The measurements had been carried out with an engineer's caliper ruler. The application of the technique is to provide some data on the form or shape analysis of pebbles: the flatness and the roundness of pebbles. Although the number of pebbles required for analysis depends on the variability of pebbles, many authors suggested 300 pebbles as a sufficient number for shape analysis (Cailleux, 1947, 1952; Tricart, 1951, and Poser, et al., 1952). However, the number of pebbles sampled from each site is 100, having a length range between 20 to 90 mm.

2 - The degree of slope gradients as related to each site and their particle sizes was measured by a telescopic alidade(see P. I-106-107).

These measurements obtained from the field examination of the particle sizes and/or shapes and its relation to the slope gradients, are to be analyzed and discussed in the following chapters.

Laboratory procedure for size analysis

Preparation of samples for analysis

Each sample has to be dried for two hours in the oven at a temperature not more than 45°C. Then it should be left exposed to the air of the laboratory for at least one hour to get to equilibrium with the room moisture. The desired amount of the sample could be obtained by splitting and quartering, then it is weighed to nearest 0.01 g. and recorded in the data sheet as the sample weight before treatment.

The sediment is then treated for the removal of organic matter and soluble salts. To remove organic matter 120 ml. of 6% H_2O_2 ('hydrogen peroxide')/

peroxide' was added to the sample while it is under a mechanical stirrer. This was then placed in the oven for one hour at 40°C. Just before the end of the time it was brought to boil to remove excesses H_2O_2. 800 ml. of deionized water was added to the mixture and it was left overnight to settle by gravity. Next day the clear liquid above the sediment cake is to be syphoned off and the sediment to be dried in the oven. After drying, the sample was weighed and recorded in the sheet as the sample weight after treatment or the original sample weight.

Dispersion

Sodium hexametaphosphate 'Calgon' was used as a dispersing agent in 10% concentration. A standard volume of 20 ml. per 1 litre used to disperse the sediment where it had been left overnight to make sure that no flocculation occurs. Next morning, if no flocculation occurred, the mixture is ready for separation.

Sieving

The separation for the sieved size fraction and fine material is to be done by wet sieving through a 240 B.S. sieve. All fine particles washed through the sieve by deionised water are collected in a 1000 ml. graduated cylinder. The material retained on the 240 sieve was dried in the oven at 100°C. After breaking the lumps with fingers, the coarse fraction retained on the 240 sieve was weighed and recorded as residue from wet sieving which is, in fact, original material weight for dry sieving. The difference in weight between the original sample and the residue from wet sieving is the weight of material collected for pipette analysis.

A/

A nest of new British standard sieves for dry sieving was built up in the following order of mesh sizes from top to bottom: 4, 8, 16, 30, 120, 240, and a lid and a receiver. The opening sizes of these sieves and their phi transformation for size diameter is shown in figures 31 - 34, and figures 41a - 45b.

The material retained on the 240 wet sieve was poured into the nest of sieves and shaken by the mechanical shaker for twelve minutes. The fraction retained on each sieve was brushed into a container and then weighed to nearest 0.01 g. and recorded as material retained on that sieve.

The fine fraction which had been collected on the receiving pan was either added to the cylinder containing material from wet sieving, that was if the total weight of material passed through the 240 wet sieve less than 2.5 g. Or it would be weighed and recorded as material passed through the 240 dry sieve, that is if the material collected in the cylinder from wet sieving was more than 2.5 g.

Pipette Analysis

A table based on Stoke's law and Wadell's formula had been calculated to determine the particle sizes of the very fine materials in relation to the size of quartz grain specific gravity 2.6 at a temperature of 20° C. A water bath with a thermo-stirrer was provided to/

to control the suspension temperature in the graduated cylinder. To enable an easy movement of the Andreason pipette over the water bath, the pipette was fitted to a carrier high enough to move over the six cylinders in the bath.

The first pipette withdrawal had been taken 20 minutes immediately after stirring the suspension in the cylinder at the depth of 20 cm. from the top of the mixture. Stirring the suspension in the graduated cylinder, in the aquarium, was done by a stirring rod, a device described by Krumbien (1938 in: Krumbien & Petijohn 1938), Griffiths (1967), and Galehouse (1971 in: Carver 1971). The suspension stirred by inserting the rod into the cylinder and moving it up and down very rapidly for at least one minute.

As soon as the rod was withdrawn, the time was noted by stop-clock. 20 ml. of the homogeneous mixture in the graduated cylinder ready for analysis, was sucked by a pipette at the fixed time and depth. The depth of the pipette into the suspension is controlled by a stand which will be described later. The material sucked through the pipette was, then, transferred into a 50 ml. evaporating dish and left to dry. The weight of the residue in the evaporating dish was determined by an analytical balance to nearest 0.001 g.

The procedure for weighing was as follows: each dish had been marked/

marked and weighed dry, then recorded as the weight of empty dish. It was filled with the material in the pipette and weighed again when it was dry. The weight of the empty dish was subtracted from the second weight to represent the weight of the residue in the dish.

The calculation of the particle size weight percent obtained by pipette analysis was done according to the following procedure. Since each graduated cylinder used for pipette analysis contains 2 g. of sodium hexametaphosphate, it follows that each pipette withdrawal contains 0.004 g. of the dispersing agent. Subtracting this amount from the weight of residue in the evaporating dish will yield the total weight of the particular fraction in 20 ml. of suspension.

The 20 ml. of the mixture withdrawn by pipette is 1/50 of the total volume in the graduated cylinder. The total weight of this particular withdrawal will be, therefore, found by multiplying the weight of the residue by 50.

The material in the successive grades can then be found, by subtracting the weight obtained by the first pipette withdrawal from the total weight of fine material in the cylinder. The second pipette withdrawal from the first to obtain the next grade scale and the third from the second and so on. These weights or the fractions of the successive grade scale could then be easily converted into percentages of the original sample weight. These percentages can then be used for cumulative percentages and curves as well as for the computation of the moment/

moment statistics. The results of the combined technique, sieving and pipette analysis, are finally expressed as the size distribution of the sample.

PART TWO : THE ANALYSIS OF PEDIMENTS AND FANS

CHAPTER 5 : PEDIMENTS

PEDIMENTS

Definition

Terminology

Pediments are the gently inclined degraded surfaces, with inclinations of not more than six degrees in most cases, and which are piedmont to mountain fronts. The half-planate surfaces of pediments are carved in hard rocks or in soft and loose rocks and they may be bare or veneered with thin fluvial and/or proluvial materials. They are mostly found between mountain fronts and valley or basin floors. They commonly form extensive bedrock surfaces over which the products of erosion from the retreating mountain fronts are transported to the basins. McGee (1897) first used this term to describe a gently sloping plane carved out of hard rock below the steeper slopes of the mountain fronts.

Several American geomorphologists have contributed to the interpretation and definition of pediments after McGee. Among these are Davis (1930), Blackwelder (1931), Johnson (1932), Rich (1935), Bryan (1936), Sharp (1940), Howard (1942), Tator (1952, 1953), Tuan (1959), Mammerickx (1964a, 1964b) and Denny (1967). The process of pedimentation and the theories for pediment formation will be discussed later in this chapter. The point to raise here is the definition of pediments. Four groups of pediments can be distinguished from the American literature. These are: proper pediments, dissected pediments, buried pediments and coalescing pediments. But several authors have used the term pediment as a synonym of the German term (Fussfläche) and the French term (glacis).

The French geomorphologists have distinguished between the typical pediment/

pediment surfaces carved in hard rocks, and glacis sculptured in soft rock and loose deposits. It will be very interesting to see whether it is necessary to establish a genetic distinction between glacis and pediment.

Glacis Dresch (1957) pointed out that glacis are sharply distinguished from pediments by their sculpture in soft rock and loose deposits. Birot and Dresch (1966) suggested three groups of glacis in soft rocks or loose deposits. These are:- i) Glacis of erosion or ablation which are truncated soft rock outcrops on the surface and might be covered by a thin sheet of alluvial deposits. ii) Buried glacis or ancient glacis of erosion which are covered by a sheet of alluvial-proluvial sediments and on which the accumulation is faster than the denudation. iii) Glacis of accumulation (glacis fans or bajada) which resemble gently sloping alluvial fans. Glacis according to the French authors are formed under arid or semi-arid climatic environments.

Pediments, however, have been defined as half-planated surfaces which occur as a transition between the highlands and the lowlands, and they are known as degradational surfaces produced by sub-aerial processes. When glacis have pediment characteristics they are in soft rocks, defined as glacis d'erosion but when they form bajada they are defined as glacis d'accumulation.

Bajada (piedmont alluvial plain or glacis d'accumulation). The bajada is a series of confluent alluvial fans along the base of a mountain range. It is underlain by gravelly detritus that is commonly ill sorted and poorly stratified. The convexities of the component fans import to the bajada an undulating surface.

Hillslope/

Hillslope (Khashm) The steep slope above a pediment and/or bajada is known in Arabic as Khashm. Since there is no particular term for these slopes they will be called here hillslopes or Khoshūm (singular khashm). They form distinct features in arid and semi-arid lands with a sharp angle between the top of the hills above and the pediments and/or bajada below. The hillslopes rising above the profiles of the pediments are more than 25° and are covered by large debris. These hillslopes commonly exhibit one or more free faces.

The occurrence and the theories of pediments

Where do pediments occur?

Many geomorphologists believe that pediments and piedmont surfaces or piedmont-glacis are arid or semi-arid landforms. Among those are Sharp (1940), Howard (1940, 1942), Tator (1952), Mensching (1968), Twidale (1968), and Bigarella, et. al. (1969). Both earlier and more recent works emphasized that pediments are mostly, if not only, formed under arid and semi-arid conditions.

Although King (1953, 1962) considered pedimentation as the most general process of planation under arid, semi-arid conditions, the seasonal tropics, the Mediterranean and to some extent the temperate climates, he believes that "pediments, though found in all parts of the world, are usually best developed in semi-arid regions", (King, 1968, p. 820). Young (1972) also emphasized that pediments are common in all tropical climates as well as the Mediterranean. On the basis of any objective definition pediments, according to Young, could be found in the temperate and polar zones (Young, 1972, p. 204).

In/

In fact research from almost every climatic zone of the world tends to indicate that pediments and pedimentation do occur everywhere. But the process of evolution might be different from one climatic zone to another and from place to place owing to the differences in the conditions of their development. It may be correct to suggest that the two types (pediments and bahadas) are well developed under arid and semi-arid environments. It could be because of many factors such as the seasonality of wet and dry periods and the development of rock disintegration in the absence of vegetation cover. It has been proved that pediment development as well as the formation of glacis occurred during the phases of arid and semi-arid environments in a much broader climatic range than some authors believe it used to be. Examples are given by Dumas (1966a, 1966b), Pecsi (1968), Tricart (1968) and Starkel (1965).

Although some authors believe that true pediments are restricted to semi-arid regions, many others believe that pediments could develop also in temperate sub-humid regions. King (1962) considers the development of pediments possible in a tropical climate of alternating wet and dry seasons. According to King, the difference between the forms developed under various climates is merely a degree of development. It should be added here that the tropical pediments are commonly distinguished from the others by a greater degree of chemical weathering.

The Theories of Pediment Formation

McGee (1897) was among the earliest workers who related pediment formation to sheet erosion. His theory is that the detritus moved by slope wash is capable/

capable of powerful abrasion leading to planation of the hard rock of the mountain fronts. In fact, sheet erosion can be regarded as one of the modifying agents in pediment formation. But numerous authors do not consider it as the formative agent which is responsible for fashioning the details of pediment formation. Blackwelder (1931) and Johnson (1932a) argued that planation is due to lateral erosion and corrosion by rivers and torrents in semi-arid regions. Many mountain fronts are comparatively straight in plan, with the maximum pediment slope at right angles to the lines of the knick. The presence of water running along the knick, therefore, cannot be approved under such circumstances. If the theory of lateral erosion is correct, then it is very difficult to see how such features as the smooth surfaces of some pediments could survive. At the head of a pediment, mountain streams become extensively braided in most parts of the study area. The migration of small channels could have some effect on the regrading of a pediment but it is not surely the fundamental process.

Davis (1930), Rich (1935) and Sharp (1940) consider the mechanical wearing of hard rocks, slopewash and lateral planation as the most important factors in pediment formation. According to Rich (1935), pedimentation, together with the production of detritus and the formation of alluvial fans, is the normal form of arid and semi-arid planation. He also supported the opinion that considers the role of lateral erosion to be inessential to the formation of pediments.

In contrast Howard (1942) demonstrated basal stream undercutting. He argued that lateral planation by both streamfloods and sheetfloods leads

to/

to the continual extension and lowering of the pediment surface. He concluded that "in as much as development of the pediment depends on recession of the base of the slope, lateral planation is the essential process in pediment development", (p. 134).

King (1948) has shown that the usual situation over most of Africa is that pediments are not confined to the margins of enclosed basins, or to similar morphological positions, but are equally well developed where the local base-level is stationary or even falling as a result of stream incision. Pediments, according to King, formed not at the base of fault-scarps but beneath the retreating walls of stream-cut valleys.

Pediments may frequently be the result of a combination of several exogenic agencies rather than the result of a single one. In the central parts of Saudi Arabia the sequence of pediment formation seems to have been developed in relation to an intermittently falling base-level. The basal slope development at the foot of the steeper slopes together with the mechanical comminution of hard rocks as well as slope wash, lateral erosion and sheet erosion are more likely to be the combined fundamental processes under which typical pediments have been developed in the central parts of Saudi Arabia. The result is a slope of transportation over which materials weathered from the steeper slopes are moved either into a stream or to an area of aggradation.

Semi-arid climates appear most suitable for pediment evolution. There is more evidence from the arid and more humid areas which shows that semi-arid conditions existed at least during the Pleistocene. Several authors have attributed/

attributed a favourable role to Pleistocene semi-aridity in most parts of the tropical arid lands, including the Middle East (e.g. Buringh, 1956, Butzer, 1958a, 1958b, 1961, 1965, 1966, Voûte and Wedman, 1963, and Wright 1958, 1961a, 1961b, etc.).

The forms of pediments in the study area and the processes of evolution are also influenced by lithology. The relationships between the steepness of the mountain fronts and the gradient of pediments are more than suggestive. The slopes of the mountain front appear to retreat parallel to themselves during the pediment formation. As a result the pediment slope advances against the main mass of the mountain in which the retreat can be determined. The slopes of some mountain fronts are determined by the angle of the weathered materials lying on them, and the gradient of the pediment is similarly controlled by the calibre of material which must be transported across it. This argument supports the observation that well defined pediments in some parts of Central Saudi Arabia are particularly evident in those parts where rocks have undergone block and granular disintegration. The possibility that both vertical and lateral fluvial erosion may be important still exists (see plates 3 and 4).

A problem which has not been investigated here is the possibility that a pediment may be maintained by running water action but without being sculptured by it and that lateral erosion after all is not the dominant factor in pediment formation. Another point to be raised with not much evidence at present is whether sheetwash rather than channel erosion is another factor playing an important role in the development of a pediment.

The/

The belief, however, is that a pediment in order to develop as a true erosional surface requires a number of factors. Such factors are a falling base-level, perhaps with slope retreat, drainage diversion, lateral planation, and above all a sequence of climatic phases of long wet and dry periods. In other words, a pediment may form as a result of a more complex interaction between agents of processes than has been generally appreciated. In fact, the whole concept of pediment development should be investigated in view of a world wide evidence rather than in terms of local conditions. The complex interaction of several processes operating on different forms could account for the apparent contradictions of interpretation.

The Pediments of the Study Area

The term pediment, here, refers to the comparatively gentle slope that exists below a steeper slope and is separated from the hills above by a sharp break of slope. They are formed in bedrock (hard rocks) and sometimes they are covered with smooth but relatively thick fluvial and proluvial materials. They are in most cases concave in profile and have less than 5^{o} of slope angle. They usually occur in conjunction with a hillslope and a piedmont angle. The energy of the system depends upon the height of the hills above the pediments, the type of rocks and their resistance, the climatic influence and the local base level. The energy performs work through many agents such as running water, weathering and mass wasting in order to maintain the steady state of pediments (see p. I-103). The state of the pediment is dependent upon the ratio between the rate of loss and gain of materials

through/

through the continued efforts of the agencies of denudation.

The pediments of Central Saudi Arabia have two systems of stream channels; those that head in the adjacent hillslopes and others that rise on the pediments and are tributary to the streams from the hills above. This can be supported by the argument that the hills above shed coarse detritus to the adjacent pediments, where the materials are stored, until they are weathered and/or transported. The supply of the eroded material increases downslope in the hillsides while it decreases rapidly down the pediment surface. Such action would result in the amount of debris supplied to the upper parts of a pediment being greater than the amount supplied to the lower parts, while the rate of debris removal from the pediment surfaces would be more or less uniform. Therefore, smaller pediments would have more coarse material over their surfaces than the larger pediments.

The pediments studied are in those areas where the mountains are of resistant rock and the climate now is arid. The pediment at Khashm Qraydān (A) illustrates the development of surfaces such as those in areas of high relief and active denudation. The pediment here is comparatively small in length (does not exceed 1150 metres) and is irregular. The annual precipitation in the area is between 100 - 200 mm. a year. The hills are of resistant limestones and dolomites, furnishing very coarse detritus to the pediment (see figs. 15a, 25, 25a, plate 5, and table 26).

On the other hand, the pediments at Wadi Al Quway'iyah (B) are longer (1350 m.) but less wide, more dissected than those at Khashm Qraydān and the/

the precipitation is between 50 - 100 mm. a year. The hills are alternate layers of limestone and igneous and metamorphic rocks which furnish slightly different shapeddetritus to the pediments than at Khashm Qraydān)see figs. 13a, 25, 25a, plate 6, and table 27).

Both areas have a hot arid climate where rainfall is unreliable but periods of relative drought may be followed by heavy rains and flooding. The mean temperature is higher and the average rainfall is less than the other parts of Saudi Arabia, excluding the interior of Rub-Al Khāli. Much of the rain falls in winter when it does and the seasonal and diurnal temperature ranges are those of the hot deserts. This means that during winter the minimum temperature at night may fall well below freezing. Winter day temperature, however, may be warm, although the winds on occasions lower the temperature level below the freezing point.

Sparse vegetation is characteristic on alluvial and fluvial surfaces, but the rock surfaces are completely bare. The geology and the physiographic characteristics of the area have been dealt with previously (chapter 1).

The comparison between the two pediments (A) and (B) (see figs. 13a and 15a) in the study area makes it very difficult to accept a single agent as the determining factor in the development of a pediment. Most of the measured profiles (fig. 25a) show a generally concave form. However one longitudinal profile exhibits both convex and concave forms. Gullies in both areas are undercutting side slopes of the embayments in a different manner. Furthermore steep gullies are entrenched on the alluvial deposits at Wadi Al-Quway'iyah, while at Khashm Qraydān the gullies are shallow.

The water flowing along the surface of the pediment B does not move directly towards a playa, but is funnelled into valleys (see fig. 13 a, Pediment B)/

Pediment B). At the apex of the funnel, namely at the entrance into Wadi Al Quway'iyah, erosion, according to some authors, should be strong and mainly in the form of downcutting. If at this point downcutting were indeed strong the surface of the pediment would be immediately dissected by streamfloods. This has not occurred in the case of Wadi Al Quway'iyah because resistant rocks (see table 27) present a local base level of erosion which protected the pediment from dissection. The survival of a thick blanket of alluvium is therefore covering the pediment as a result of the temporary base level of erosion.

Relationships between sheetfloods and pediments in terms of cause and effect are not simple or easy to determine. The suggestion that the production (origin) of pediments is due to sheetflooding is to state that sheetfloods are the cause of pediment formation. In the writer's opinion, considering sheetfloods as the sole process responsible for pediment formation is not a warranted argument. Although sheetfloods have been reported to have operated effectively on pediments, the claim that the origin of pediments is due to such a process is based on an assumption concerning cause and effect. This is so because sheetfloods may equally be a result of pre-formation of the pediments by other processes. The bedrock surfaces of the pediments may also have existed prior to sheetfloodings. Remodelling of these surfaces may result from sheetfloods, but so far there is no evidence that such events are the cause of pediment formation.

Lateral erosion also cannot be ignored as a process that affects pediment development and reworking of the pediment surfaces, because channels will undoubtedly through time migrate on these surfaces. But the pediment formation cannot be explained only in this manner. If the assumption is that lateral erosion/

erosion is responsible for pediment formation, then such an assumption, according to Lustig (1969), would require all channels emerging from the mountains to turn, occasionally, sharply to one side or another, cutting back the mountain fronts in interfluvial areas. He further noted that "such stream paths, nearly perpendicular to a sloping surface, would defy the laws of gravity and have not been observed except those in areas where drastic tilting has occurred", (Lustig, 1969, p. D65 - D66).

The retreating slopes of the mountain fronts may retain characteristic slope angles as a reflection of rock resistance, structure, and weathering. King (1967) noted that "In many districts, hillslope elements exhibit remarkable uniformities of gradient which could be so only if the hills, large and small, had maintained throughout their erosional history a reasonably stable angle of slope; that is if the slopes and scarps had retreated parallel to themselves", (p. 148 - 149). Although most escarpments are liable to parallel retreat, this does not indicate that mountain ranges are reduced only by parallel retreat of escarpments. Observation on Khuff escarpments and Tuwayq escarpments in Central Saudi Arabia provides evidence for the existence of an integrated drainage network. Even on smaller scale, the Khuff outcrop at Wadi Al Quway'iyah and the Tuwayq outcrop of Khasm Qraydān show the existence of drainage channels. This supports the argument that the reduction of the mountain ranges cannot be explained only by the parallel retreat of escarpments even in the driest parts (some parts of Central Saudi Arabia are very dry with about 50 mm precipitation).

Parallel retreat of escarpments (with different rock resistance) may lead to the formation of pediments, but it cannot be the only cause of such formation because the principles of this hypothesis ignore the role of major drainage/

drainage courses from the mountains. In the writer's opinion, it is very difficult and problematic to seek a single explanation for pediment formation because there are always some local variations of the landforms, and processes are not constant through time or in space. Generally, the pediment lies between zones of erosion and deposition and its boundary will be largely determined by the relationship between the rates of debris supply and removal. If the erosional processes are dominant over the debris supply, the bedrock surfaces of the pediments may be exposed as the channels migrate downslope (see Mabbutt, 1966). The pediment may have been formed and may be extended by the parallel retreat of escarpment and the reduction of the mountain ranges due to the effective operation of the erosional processes over the drainage basins through time (see Lustig, 1969). If the rock resistance is generally uniform (as in crystalline rocks) and the debris supply is equal to or more than the removal, then weathering is an important factor in pediment development. Mabbutt (1966) noted on the granitic and schist pediments of Central Australia that "....what has been involved in pedimentation has been slight back-trimming at the hill base, partial weathering of an irregular, exhumed weathering front and the impositions of continuous, concave profiles...", (p. 91), see also Ruxton and Berry, 1961, Thomas, 1966, 1967 and 1974).

Finally, the development of the bedrock surfaces of pediments (in terms of eroding and remodelling of these surfaces or depositing onto them) may have been brought about by sheetfloods, lateral erosion, and/or other processes. Whether pediment formation is the result of escarpment retreat, mountain reduction through time, mantle-controlled planation, exhumation, or lateral planation is still a speculative matter.

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In search of a definition of pediments the field observation has added to the confusion. When sampling the alluvial cover, sediments were excavated from 4 metre depths: - a phenomenon unusual in the case of true pediments so far defined by several authors. Were the features sampled proper pediments? This question led to the investigation of the sediment properties in relation to slope, distance, and depth. Further, it is considered possible that the shape properties of pebbles (which make up a large proportion of the gravel covering the surfaces) might reveal more information concerning the problem of definition.

The Analysis of Pediment Sediments

Particle Size Analysis and Pebble Shape

The relations between particle size, pebble shape and slope were investigated along traverses of two pediments on limestones and other types of rocks in some parts of Najed, Central Saudi Arabia (see tables 26 and 27). Two methods of grid sampling were used; the large particle grid and the fine particle grid. The method for measurement and the procedure for the laboratory work have been described in the introduction to this part of the thesis (chapter 4).

A contrast is recognized between debris on limestone surfaces (which are characterized by the larger particles) and debris on other rock types (which consists of a mixture of large, medium and small size particles). Therefore two areas were selected for study; one dominated by limestones and the other by limestone and metamorphic and igneous rocks (compare plate 5 with plates 7 and 8). Traverses were surveyed by levelling the longitudinal profiles of pediments and fans. The only departure from common levelling technique was the use of a telescopic alidade (mounted on a plain table) instead of a levelling instrument. The alidade was the only instrument available to the author/

author at the time, but gave results of reasonable accuracy. Sites for pebbles and finer materials at given depths were generally chosen at 200 metres intervals (see fig. 25). At each site a one square metre grid was placed on the ground. Intersections on this grid were numbered from 1 to 100 and 100 pebbles from each site were measured in the field. These particles were above 20 mm. in diameter. For particles smaller than 20 mm. samples of 500 grammes were taken from each of five depths at every site (surface, 1m., 2m., 3m., and 4 m. depths). These samples were brought to the laboratory where they were analyzed by means of sieving and sedimentation methods. From each pediment more than 500 pebbles were measured for shape analysis. For particles smaller than 100 mm. and larger than 4 mm. the following representative values were selected from measurements on samples obtained from both pediments. These values are the first quartile, the second quartile and the third quartile the maximum slope in degrees (which was also measured at each site), and the maximum length of the intermediate axis (b or 'M' axis). The size of each particle of this group was generalized as the length of its b axis which was measured by an engineering caliper.

The observed y values in figure 25 (heights in metres V and X, the first quartiles IV and IX, the second quartiles III and VIII, the third quartile II and VII, and the maximum lengths I and VI - measured from the size frequency distribution of particles above 4 mm. in diameter -) were plotted against the x values (distance interval sites from the mountain fronts) in a simple linear regression. Thus the relationships between particle size properties (above 4 mm.), slope, and distance can be visualized. Although the number of the observed values is not sufficient for the t-test of significance, the distance interval is large enough for correlation. The average mean sizes of particles smaller/

smaller than 4 mm. and the thickness of alluvium (as measured at the sites) are also shown in figure 25.

The sedimentological shape of rock fragments is one of the principal factors in the interpretation of transportation and deposition of the fragments themselves. The roundness of the corners and edges of these fragments may indicate the vigour of the present stage of transportation. Increase in the evidence of transportation would increase fracturing and chipping in the load and reduce the roundness of the corners in general. Rounding of sedimentary particles is a special type of disintegration (abrasion) associated with attrition and sometimes solution. A high degree of roundness is often an indication of gentle conditions of wear relative to size and the degree of hardness of the particle.

The methods used for measurement of pebble variables are those adopted by Sneed and Folk (1958) and Cailleux (1945). The variables required for shape determination are: the length of the long axis of pebbles (L), the length of the intermediate axis (M), the length of the short axis (S), and the smallest radius of curvature (R_1) in the plan defined by the axes L and M. The first three measurements were obtained by using calipers. The minimum radius of curvature was determined by constructing a transparent "Wadell circular scale" which was placed over the corner to be measured and the minimum radius of each corner is then determined. The parameters calculated for the shape of pebbles are as indicated by the following formulae:-

The/

The Volume $= V = \frac{\pi}{6} \times L \times M \times S$;

The Maximum projection area $= Pr = \frac{\pi}{4} \times L \times M$;

The Maximum projection sphericity $= \mathbb{D} = \frac{S^2}{L \times M}$;

The Flatness $= Fr = \frac{L + M}{2S}$; and

The Roundness $= R = \frac{2R_1}{L}$

if the roundness index of a sphere is put equal to 1,000 instead of 1, then the above formula will become;

$$R = 2000 \times \frac{R}{L} .$$

Then the form class has been calculated for each pebble. The form as defined by Sneed and Folk (1958) is the ratio between either

$$\frac{(L - M)}{(L - S)} \quad \text{or} \quad \frac{(S)}{(L)} .$$

If $\frac{(S)}{(L)}$ exceeds 0.7 then the particle is said to be compact. For values of $\frac{(S)}{(L)}$ less than 0.7, the form classes of pebbles from each site of both pediments are summarised in table 32.

The/

The frequency distribution of the shape parameters is obtained by counting the number of pebbles in each class interval (which is 15,000 units for volume values, 400 units for the maximum projection area values, 0.05 units for sphericity values, 0.30 units for flatness values, and 50 units for roundness values) over the length of 20 classes. The moment statistics for the distribution of each shape parameter are then calculated giving the mean, the standard deviation, the skewness and the kurtosis values.

<u>Pebble Shape on Khashm Qraydān and Wadi Al Quway'iyah Pediments</u>

<u>Roundness</u> As shown in tables 15 - 25, tables 28 - 31, the roundness of pebbles from both pediments increases as we travel down either pediment to a distance of about 1200 metres from the hillslope. The roundness increases from 256.756 at 150 m. from the hillslope at Khashm Qraydān to 292.282 at 650 m. and 370.882 at 1150 m. At Wadi Al Quway'iyah it increases from 212.119 at 100 m. from the hillslope to 264.805 at 950 m. and 299.515 at 1350 m. The t-test ($\bar{a}$ = 0.25) proved that the increase in roundness is extremely significant for both localities (see tables 28 and 30). The standard deviation ranges from 106.184 at 150 m. in Khashm Qraydān and 68.549 at 100 m. in Wadi Al Quway'iyah to 121.236 at 650 m. in Khashm Qraydān and 129.014 in Wadi Al Quway'iyah. Down the pediment 1150 m. from the hillslope in Khashm Qraydān and 1350 m. in Wadi Al Quway'iyah the standard deviations are 154.130 and 155.482 respectively. Again the variance ratio tests show a significant variability (at 95%). The reason could be that the pebbles may be of many diverse types. But in Khashm Qraydān (where there is only a major type of rock) it could be that different kinds/

kinds of lithology in the limestone group have produced such variability, or it could be because the least round fragments are static. Denny (1970, p. 665) concluded that the roundness index, specially on slopes above the pediment head, tends to increase in value in the down-slope direction (compare table 28 with table 30).

The detailed study of the roundness variation between each of the eleven sites on the two traverses shows no significant changes between the first two sets in each site. It also shows no significant changes between the last two sets in each site. Yet if the first two sets are to be compared with the last two the increase in roundness is significant. Another point worth making is that the sites at 650 m. in Khashm Qraydān and 600 m. in Wadi Al Quway'iyah seem to fall closer to the first two sets rather than the last two.

<u>Sphericity</u> As could be deduced from tables 15 - 25 larger pebbles seem to show slight changes of sphericity with size in both sites. Although many authors have found no significant change of sphericity with size Sneed and Folk (1958) found some significant change of sphericity in the chert and quartz pebbles and none in the limestones. The smaller size of pebbles seem to have higher sphericity than the larger. As far as the distance from the hillslope is concerned the change in sphericity of pebbles from both pediments is not significant. The sphericity at 150 m. from the hillslope in Khashm Qraydān is 0.707 and at 100 m. in Wadi Al Quway'iyah is 0.699. At 650 m. it is 0.718 in the former and 0.694 in the latter. Further down the pediments the sphericity ratios are 0.735 and 0.679 respectively. This is probably due to the variability

of/

of pebbles in the latter pediment which means that a mixture of different types of pebbles might keep the sphericity in a constant pattern. For Khashm Qraydān the possibility is that the shape of the rock fragments when separated from the blocks of outcrops might have some influence on the trend of sphericity during transportation. The sphericity behaviour of the limestones even if mixed with few pebbles of other kinds shows a more or less constant ratio. This again was detected by Sneed and Folk in the Lower Colorado river (see Sneed and Folk, 1958, pp. 130 - 141 and tables 29, 31).

Form Although the assumption that limestone pebbles would be of the platy form because of their bedded structure, the results (tables 15 - 25) show that pebbles from Wadi Al Quway'iyah (mixed rock) have an average of 41.2% of the bladed, very bladed, or compact bladed category while the pebbles from Khashm Qraydān pediment have an average of 36.8% of that category. The platy forms are 24% among the pebbles of the former pediment and 20.4% among the latter. Elongated and compact forms have an equal number in first case (17%) and 16.8% elongated forms and 26% compact forms in other pediments (see table 32).

The forms are shown for individual pebbles in tables 15 - 25. From these tables and figures 78 - 110 it is clearly seen that the bladed categories have about twice the number of pebbles when compared with any other category. This concentration is not restricted to the type of rock or certain features. But as it has been shown by Sneed and Folk (1958) it does exist among the pebbles of the river Colorado in all types of rocks.

The/

The frequency distribution shown in table 32 and figure 25 again represents a close relation between the data obtained from the pediments which consists of 1100 pebbles and the data obtained from 1150 pebbles by Sneed and Folk (see Sneed and Folk, 1958, p. 146). The data show about similar concentration of the bladed categories. Approximately 40 percent represent the bladed categories and 22 for each of the other two groups (28% of the pebbles are compact forms). There is no need to assume any particular explanation, since it could be a coincidence that the same results have been obtained with different operators and in different places. The reason could be that the pebbles tend to concentrate in one category rather than the others during one stage of their movement and then might concentrate in different groups during later stages in their development.

Particle Size Analysis of Sediments finer than -2 phi

The cumulative frequency distributionsfor particles less than 6 mm. were obtained by sieving and sedimentation and are plotted in figures 26 - 45b on probability paper and logarithmic graphs. These graphs show the behaviour of sediment in relation to distance from the hillslopes as well as the changes, if any, within certain depth categories. The statistics from the first four moments for the frequency distribution are given in tables 33 - 82. The tables have been arranged so that their sequence represents the surface materials on the traverse interval points, then the next depth category which is one metre below the surface. The sequence of the tables is carried on in this manner to the last depth category along each traverse.

Mean/

Results of Size Analysis:

1. Mean Size: All samples from traverse A (pediment in Khashm Qraydān) average about 2.84 phi with standard deviation of 2.10 phi. That is to say they lie within the fine-sand size range. The samples from traverse B (pediment in Wadi Al Quway'iyah) average about 1.34 phi with 2.56 phi standard deviation. The comparison between the two pediments suggests that traverse A has a mean size finer than traverse B. The reason for this could be that in pediment A the limestone of the parent rocks wears more rapidly than those in pediment B, so that more fine sediment has been developed. The detailed analysis of the mean sizes in relation to distance and depth shows different trends. The mean size of samples from traverse A increases significantly as we travel down the pediment. The mean size at 150 m. from the hillslope is 1.42 phi with standard deviation about 2.42 phi. This increases to 3.14 phi with S-average 1.85 phi at 900 m. and to 4.85 phi with S-average 1.92 phi at 1150 m. from the hillslope (figs. 21 - 24).

The t-test shows significant changes in the mean sizes of samples from traverse A (pediment A) with distance at P_o.01 and P_o.05 levels. Traverse B (pediment B), on the other hand, consists of finer sediments than traverse A and the size/distance relationships show no significant increase or decrease. The fines in the samples from pediment B seem to concentrate at the 600 m. and 1350 m. sites while a coarser mean size seems to concentrate at 1100 m. site. If one considers the mean sizes at 100 m. and 1350 m. sites, these two sites show some changes in the mean size even though the test shows no significant relationship between size and distance.

Although there is a slight kick in traverse A at 400 m. site in the cumulative curve (fig. 29), the trend seems to agree with the results obtained by the moment computational method. However, this point is further discussed in/

in the section dealing with graphic interpretation of the size distribution (p.I-123). The moment method shows that most of the mean sizes of clastic sediments from both traverses (A and B) lies between +1 phi and +5 phi. In other words, most of the samples from both pediments would be classified as coarse to very fine sand with gravel and silt tails.

Pediment A samples have averaged coarser mean sizes than pediment B. The average mean sizes of pediment A samples are between +2 phi and +1 phi (0.5 - 0.25 mm.), about the size of blown sands. Most samples have about 1-30% silt, averaging 10%, but most of the silt fraction is more than 0.22 mm., (5.5 phi).

2. Sorting: All samples from pediment A average σ_ϕ = 2.1 phi and the S-range = 1.85 to 2.42 phi. Pediment B samples, on the other hand have an average σ_ϕ equal to 2.56 phi and the S-range = 2.28 to 2.75 phi. In other words, both pediments (A and B) have poorly sorted clastic sediments (tables 33 - 82). Samples from pediment B, however, have twice as wide a spread in the grain-size distribution as the samples from pediment A (figs. 26 - 45a and tables 33 - 82).

The clastic sediments on pediments A and B are variable in their particle size properties. They consist of a large proportion, by weight, of gravel (30 - 40% in many cases) as well as silt (about 30% in a number of cases). Consequently, the σ_ϕ values are high (see for example tables 46/p. II-59, 48/p. II-63, and 55-62/pp. II-79 - II-93). In particle size distributions with high σ_ϕ values, there is a greatly increased probability that the position of the mode is located at one or other end of the distribution, away from the median. In such cases, the determination of the higher moments is biased towards extreme values. It seems that the variation in SK_ϕ and K_ϕ for the pediment clastic sediments is a consequence of the extreme position of the mode/

mode in 80% of the total samples. The use of the percentile measures of skewness and kurtosis offers no advantage in this case since the particle size mode of the samples lies outside the central 50 percent of the cumulative curves (see A-24/fig. 28, A-26/fig. 27, B-2 to B-5/fig.30, and B-6 to B-10/ fig. 36).

3. Skewness: About 70% of the samples collected from pediment A are positively skewed. More than 82% of the samples from pediment B are also positively skewed. However, pediment A samples show greater skewness (+1.14 phi) than pediment B samples (+0.53 phi). The average skewness of all samples from pediment A is about SK_{ϕ} = +0.13 phi and the S-range = -0.004 to +0.53 phi. About 75 percent of the negatively skewed samples are more negatively skewed than -0.01 phi but none of pediment A samples are negatively skewed less than that. Most of the samples from pediment B are not strictly unimodal but contain an admixture of populations in -2 to 0 phi, 0 to +6 phi and +6 to +8 phi giving the variation in skewness (compare this with the results of graphic measurements). Samples from pediment A, on the other hand, are more likely polymodal giving a wider range of skewness values.

4. Kurtosis: All samples from both pediments are platykurtic averaging about K = +0.38 phi, (K'_{ϕ} = K(K+1) = 0.28), and the S-range = K = 3.63 phi to -0.19 phi. The average K value of samples from pediment B is K = +1.02 phi to -0.1 phi. However, the kurtosis variability reflects the modality of the size distribution of the samples from both pediments (A and B). The/

The variability of kurtosis is perhaps due to the contrasting features of samples A and B both of which have platykurtic distribution curves. Deficiency of certain sizes could also result in a variation of kurtosis values which tends to produce platykurtic or flattened distribution curves.

5. <u>Analysis of variance</u>: The analyses have been carried out on the average particle size parameters (namely the mean, the standard deviation, the skewness and the kurtosis) in relation to distance and depth. The experimental design shown in tables 83 - 91 is a two-way classification, analysis of variance experiment. It has been designed to compare two procedures of sampling pediment sediments. The samples have been collected so that they will represent a number of sites on a pediment traverse at fixed distance and depth intervals. Thus for the experimental layout there are two factors A and B, where A has r levels $A_1, \ldots, A_r$ and B has p levels $B_1, \ldots, B_p$. To study the effect of distance (factor A) and depth (factor B) on the grain size parameters (variable X) a sample of $n = rp$ values x_{ik} $(i = 1, \ldots r, K = 1, \ldots, p)$ have been collected and analyzed. The results of the size analysis are those random variables (which are obtained as the moment statistics for the frequency distribution of/

of particle size) on which the effect of factors A and B will be performed. In this two factorial design the value X_{ik} is an observation on X when level A_i of the factor A and level B_k of the factor B are present. Thus X_{ik} would be regarded as an observed value of a random variable X_{ik} with the following hypotheses:

Ho_1: states that all those mean values are equal, that is to say, those random variables X_{ik} have exactly the same normal distribution. This would mean that factors A and B have no effect on X (distance and depth have no effect on the particle size parameters), and the sample values differ only because of random variation and experimental errors.

Ho_2: states that the mean values are not equal, that is to say, that those random variables X_{ik} have different distribution and that factor A has effect on X (meaning that the distance has effects on the grain size distribution) and the sample values differ only by factor A while factor B has no effect.

Ho_3: states that the mean values are not equal because of factor B, that is to say, that the values of the variables X_{ik} are different because the depth factor has an effect on the grain size distribution and that distance has no effect on the variables.

Ho_4: states that the mean values are not equal because of both Factor A and B, that is to say, that the value of the variables X_{ik} are different because both, the depth and distance, factors have effect on the grain size distribution.

To test these hypotheses the computation for the two-way analysis of variance/

variance without replication was carried out according to the standard formulas (see Griffiths 1967 and Kreyszig 1970). The results for the analysis of variance are given in tables 83 - 91. The computation includes the row means, the column means, the grand mean, the correction factor for the sums of squares, the column sum of squares, the error sum of squares, the row mean square, the column mean square and the error mean square. The F (mean square) ratios are then given. If the F ratios are significant, the standard errors of the difference between the row and the column means are given.

From the results in tables 83 - 86 we have four depth variables (B_k) for pediment A and five depth variables for pediment B and five distance localities (A_i) for pediment A and six distance localities for pediment B. The degrees of freedom for rows (B factor) is $n - 1 = 4 - 1 = 3$ and columns (A factor) is $n - 1 = 5 - 1 = 4$ with $(n - 1)(m - 1) = 3 \times 4 = 12$ degrees of freedom. The F ratio (F_r) for the phi means of samples from pediment (A) is $= F_r = 3.9452$, and for the standard deviations of samples from the same pediment the F ratio (F_r) is $= F_r = 3.1462$, the skewnesses F ratio is equal $F_r = 1.3225$, and kurtosises F ratio is $F_r = 1.7848$. From the critical values of the F distribution tables we have the value of C_1 at $a = 0.10$ with (3,12) degrees of freedom $C_1 = 2.6055$, and the value of C_2 at $a = 0.10$ with (4,12) degrees of freedom $C_2 = 2.4801$. The F ratio for the phi means of samples from pediment A is $= 3.9452$ that means that in comparing F_r value with either C_1 or C_2 we have a significant variation due to factors A and B at $a = 0.10$ level. Considering C_1 and C_2 values at another level

a/

$a = 0.05$ we have $C_1 = 3.4903$, and $C_2 = 3.2592$. Again we have here a significant variation due to the combined factors A and B. The F ratio of the standard deviations of samples from pediment A $F_r = 3.1462$ has a significant variation at $a = 0.10$ level only due to factors A and B. But neither skewness nor kurtosis has any significant variation due to either factors. Therefore, for the phi means and the standard deviations of samples from pediment A (Khashm Qraydān) we reject the hypotheses Ho_1, Ho_2, Ho_3 and say that all those mean values are not equal due to effects of factors A (distance) and B(depth). Thus we accept the hypothesis (Ho_4) which states that the difference is due to the fact that the size distribution has been changed significantly by the depth and distance factors. (For summary of the results and test of significance see table 91).

Unfortunately there is no way at present to isolate either factor to see which factor is more significant than the other because there is no replication for either level (a_i) and/or (B_k). This would be carried out in a future work when one can add a third factor to this (estimate of the operators errors). At the moment we can only say that the distance and depth in pediment A have significant effects on the grain size parameters (means and standard deviations). But we accept the first hypothesis for the skewness and kurtosis. That is to say that these random variables have exactly the same normal distribution which means that distance and depth do not effect their behaviour. The results of the analysis of variance for pediment A samples agree with the t-test discussed earlier.

For pediment B (Wadi Al Quway'iyah) the results of the analysis of variance/

variance are shown in tables 87 - 90. From these results we have five depth variables (B_k) and six distance localities (a_i). The degrees of freedom for rows (B factor) is n - 1 = 5 - 1 = 4 and for columns (A factor) is m - 1 = 6 - 1 = 5 with (n - 1) (m - 1) = 4 x 5 = 20 degrees of freedom. The F ratio (F_r) for the phi means of the samples from pediment B (depth factor) is F_r = 1.5439, for the standard deviations F_r = 0.3227, for the skewness F_r = 0.3939, and for the kurtosises F_r = 0.6674. From the critical values of the F distribution tables we have the value of C_1 at a = 0.10 level with (4,20) degrees of freedom C_1 = 2.2489, and the value of C_2 at a = 0.10 level with (4,20) degrees of freedom C_2 = 2.2489. Therefore, for the samples from pediment B (the phi means and the standard deviation as related to depth), the variance ratio is not significant at any level (table 92, variation between depth). Thus, for the variations due to the depth factor, samples from pediment B are not significant. Consequently, we accept the first hypothesis (Ho_1); that is to say that those mean values are equal, and that depth has no effect on the grain size parameters. However, the F ratio (F_r) for the phi means of the samples from pediment B (distance factor) is Fr = 7.5512, and for the standard deviation Fr = 3.3905. From the critical values of the F distribution tables (with m - 1 = 6 - 1 = 5 and (n - 1) (m - 1) = 4 x 5 = 20 degrees of freedom) we have the value of C_1 at a - 0.01 level, with (5,20) degrees of freedom, equal C_1 = 4.17 and the value of C_2 at 1 = 0.25 level, with (5,20) degrees of freedom, equal C_2 = 3.29. Thus, the phi mean values (distance factor) of pediment B samples are significant at 0.01 level and the standard deviation values (distance factor) are significant at 0.25 level. Therefore, for samples from pediment B (the means and the standard deviations as related to distance/

distance) we accept the second hypothesis Ho_2 which states that the mean values of factor A (distance) are not equal and, thus, factor A has a significant effect on the grain size parameters (phi means and standard deviations). The summary of the analysis of variance of the means and standard deviations of samples from pediment B is given in table 92 (p. II-143).

6. Graphic measurements: Many authors in the field of earth sciences have reported the distribution of sediment particle diameters in their attempt to reconstruct depositional and/or erosional environments. Size frequency distribution of clastic sediments is usually described by four parameters; the mean or the median "the average", the spread or "sorting", the symmetry or "skewness", and the peakedness or "kurtosis" of the distribution. Computation of these parameters could be obtained by either the moment analysis or the graphic measurements. The moment analysis involves the full range of a distribution rather than percentile determinations, as in graphic measurements, which deal only with the central part of the distribution curve and may omit frequencies in the tails of the distribution. On the other hand, although the moment method deals with the whole range of the particle-size distribution, it suffers many disadvantages as the computations are complex and cannot be applied to open-ended analysis without reservations. Graphic computation is relatively simple and the interpretation of the curves is more straightforward. The parameters required for size analysis (the mean, standard deviation, skewness and kurtosis) can be calculated from the graphic measurements with an efficiency as high as 90 percent compared to the even greater accuracy of the method of the moment statistics.

Many/

Many workers have suggested a number of formulas to be used for the computation of the mean, sorting, skewness, and kurtosis by the graphic method. Inman's (1952) formulas are very simple to use but the statistics, theoretically, are independent for normal distributions. Folk and Ward (1957) modified these formulas so that the statistics are mutually independent and can be applied to non-normal as well as normal distributions. The graphic measurements and the computations of the phi means (M_z), the phi deviation (σ_1), and the skewness (SK_1), discussed hereafter, are obtained by using Folk and Ward (1957) formulas.

Figures 26 - 45b are graphic representations of the grain size distributions of clastic sediments collected (by the method described in chapter 4) as samples from two pediments (A and B) in the study area. Figures 26 - 30 and 35 - 40 are the cumulative curves (of the size distribution of sediment particle size of the above mentioned pediments) plotted on arithmetic probability papers using the phi scale for the particle-size diameter. The logic behind the use of probability paper and the phi scale is discussed by Krumbein and Pettijohn (1938).

The samples available (total 55) for the study of the two pediment clastic sediments were analysed (by the methods described in chapter 4 and discussed in appendix B) to determine the particle size and their distribution by weight percent. All particles larger than 4 mm (-2 phi) were screened out and not studied further. Therefore, this study is based on the gravel and smaller fractions.

The sediments analysed vary from gravel (if the material above -2 phi are included) to fine silt which provides a large range of sizes. Gravel percentage varies from 0 - 50 and the most common value is between 10 - 30 (figs. 26 - 30, and 35 - 40). The range of silt percentage is 0 - 50 but the common value is between/

between 5 - 15. The sand value reaches 95 percent but 45 samples out of 55 have a common value between 70 - 80 percent (figs. 25 - 45b). The sand value of 95 percent is illustrated in the curves A-18 (fig. 26), A-14 (fig. 27), A-12 and A-13 (fig. 28) and A-11, A-9, A-8 (fig. 29). This value falls to 50 percent or less in the curves A-30 (fig. 26), A-23 (fig. 28), B-6 to B-18 (figs. 36 to 37), B.23 and B.24 (fig. 39) and B-25 to B-30 (fig. 40).

The average sediment from pediment A samples lies within the silty sand population with a small percentage in the gravel fraction. The average of pediment B samples, on the other hand, lies within the sand population with a higher percentage of gravel and silt than pediment A samples. Most of the grain-size distributions illustrated by the cumulative curves (figs. 26 - 45b) are not unimodal, normally distributed curves. They rather show bimodality or polymodality. However, at least three curves (A-18/fig. 26, A-14/fig. 27, and A-12/fig. 28) approach log-normal straight lines on the probability plots. Some of the distributions are bimodal while the others are perhaps polymodal. The primary mode of the bimodal distributions fluctuates over a wide range (0 ϕ to +6 ϕ) while the secondary modes are more or less fixed in between -2 phi to 0 phi when the distributions are skewed to the coarse and between +6 phi and +8 phi when the distributions are skewed to the fine. The modes for the polymodal distributions are: a primary mode, and two secondary modes. The primary mode again fluctuates between 0 phi and +6 phi with about equal proportions of the ranges -2 phi to 0 phi and +6 phi to +8 phi forming the two secondary modes.

The probability plots of the size distribution curves show a zig-zag pattern in most cases (31 cases out of 55). A definite intersection occurs at -1 phi (A-25/fig. 27, A-2 to A-5/fig. 30, B-17 to B-16A/fig. 38, and B-21 to B-16B/

B-16B/fig. 39) and another roughly at +4 phi (A-25/fig. 27, A-13/fig. 28, A-2 to A-5/fig. 30, B-2 to B-1A/fig. 35, B-13 to B-1B/fig. 37, B-17 to B16A/fig. 38, B-21 to B-16B/fig. 39, and B-25 to B-30/fig. 40). A minor break occurs roughly at +2 phi (B-2 to B-1A/fig. 35. B-13 to B-1B/fig. 38, B-17 to B-16A/fig. 38, B-21 to B-16B/fig. 39, and B-25 to B-30/fig. 40) but for the rest of the samples +0 phi to + 4 phi is a continuous straight segment.

The intersections, mentioned above, divide, generally, the cumulative curves into different segments:

segment	range in phi
A	-2 to 0
B	0 to +4
C	+6 to +8

Segments A and C most probably illustrate deficiency of materials in those ranges. Deficiency of certain sizes in sediments has been reported by many authors (e.g., Udden, 1914, Krumbein, 1942, and Wolff, 1964).

Discussion

Particle size and shape analysis produced quantitative data which have been studied for size frequency distributions. The determination of the moment statistics and the graphic measurements, together with the data collected in the field, have provided an adequate basis for describing two pediments (A and B) in terms of size, shape and slope as related to distance along the pediment profiles and within depth of the clastic mantle covering the bedrock surfaces. The statistical analyses of the data have also provided local and inter-regional comparisons.

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The two traverses (A and B) show similar features (fig. 25). Firstly, there are negative correlations between height and distance from mountain front (V and X). Secondly, the quartile measurements of particles above 4 mm. in diameter also show negative correlation with distance (II, III, IV, VI, VII and VIII). Thirdly, the rates of particle size decrease are most obvious for the large particles (above 20 mm.), but the maximum rate is as great as the rate of slope decline. Fourthly, comparison of profiles (figs. 25 and 25a) shows that the upper ends of the profiles are associated with steeper slopes as well as larger particle size. Finally, the frequency of the particle sizes tends to be polymodal in general terms; a mode that confirms the modes of the smaller (below 4 mm.) particle distributions.

Pebble shapes show characteristics of some abrasion mechanism and transportation wear, but not significantly. Some of the pebbles studied are very angular and a large percentage is within the bladed form class with average roundness between subangular and subrounded. In other words, most pebbles have strongly developed, relatively flat faces with incipient rounding of corners, although some pebbles have developed flat faces with corners that are well rounded. These pebbles are also pitted by inumerable, minute chips and shatter marks which might be the result of collisions during transport.

The degree of pebble roundness indicates the short distance of transportation (about 2 km.). The tests show significant increase in roundness, significant decrease in size, and no significant sphericity. It is very difficult to evaluate the roundness and sphericity of freshly broken materials since most would be sharp-edged and very angular. A better-rounded gravel, although more mature than angular gravel, that is to say they may have had a longer/

longer abrasion history, does not signify the same degree of maturity as better-rounded sands. The increase in roundness with distance down the pediment with no increase in sphericity and a negative correlation with size may indicate selective transportation: that is to say that the least rounded pebbles are more static than the better rounded fragments and therefore are likely to be found in the upper parts of the pediments. Although it seems safe to say that roundness is strongly modified by abrasion and wear to which the fragments are subjected, the ratio of surface area to volume (sphericity) is important in controlling the response of particles to lifting forces. In many cases the correlation between roundness and sphericity is significant. Pettijohn (1957) noted that "of primary importance is the observation that a small change in sphericity is correlated with a rather large change in roundness", (p.61). In our case sphericity is static and roundness shows significant increase with distance. Since abrasion and wear would affect sphericity as well as roundness, it is very difficult to assume here that the increase in roundness is the result of abrasion and wear. Flat pebbles are generally less rounded and their response to lifting force and rollability in a diminishing energy downslope (assuming that the decrease in the particle size indicate such a situation) may lead to the suggestion that the better rounded pebbles are, therefore, transported further down the pediment. Since the size/roundness relationship, in our case, is inverse; that is to say that larger particles are least rounded, and that this relationship is significant, it could be argued that at a given site there is a maximum particle size that can reach this site. These are the particles of highest transportability and perhaps the least flat and better-rounded fragments.

The average grain size of the clastic sediments (less than 4 mm.) of pediment A is finer than the average size of pediment B sediments. Pediment A has

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an average mean size of 2.8 phi and pediment B has an average mean size of 1.3 phi. Both samples show poor sorting and bimodal or polymodal frequency distributions which are skewed to the coarse or the fine and have playtokurtic characteristics.

The analysis of data indicates that the source of the clastic sediments of both pediments has a relatively wide range of particles to supply the area of deposition. The sediments studied represent the initial breakdown of the rock to a mixture of fragments and single grains of gravel, sand and silt with a maximum transport length of not more than two kilometres from the source. The polymodal distributions resulting from this mixture can be readily seen in the coarse and fine tails of the average mean size frequency distribution curves (figs. 45c and 45d). The sites at 150 m., 400 m., and 650 m. (fig. 45c) lie between the two theoretical, normal mixing; 30:70 percent gravel to sand and 70:30 percent sand to silt, with the 650 m. site having larger gravel percentage than the other sites. Further down the pediment (site 1150 m./fig. 45c) the fitted theoretical curve has a mixing ratio of 30:70 percent sand to silt. Pediment B sediments, on the other hand, lie between the mixing ratios 30:70 percent gravel to sand and 50:50 percent sand to silt. All sites, except 600 m. (fig. 45d) have 30 percent or more of the gravel fraction which reaches about 50 percent in site 1100 m. (fig. 45d). Most samples from pediment A are characterized by the depletion of the fraction in the -1ϕ range compared with the samples from pediment B (compare figs. 26 - 29 with figs. 35 - 40). A fact that has been reflected in the average mean sizes of both pediments (pediment A 2.8 ϕ and pediment B 1.3 ϕ).

It is interesting to note that the surface material in both pediments

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has a coarser mean size in the lower parts than the upper parts with the exception of sites 1150 m. and 650 m. in pediment A, and sites 1350 m. and 600 m. in pediment B (see figs. 31, 41a and 41b). The increase of particle size with distance is also shown in pediment B samples at 1 m. depth sites (figs. 42a and 42b). The only consistent decrease in size with distance is at all 1 m. depth sites of pediment A (fig. 32), contrary to the analysis of variance results which indicate significant decrease in particle size downslope (see surface material and sub-surface sites, figs. 31, 33, 41a - 45b). But since we accept the significant decrease of the means of the particle size distribution downslope (with distance) it is reasonable to speculate that some large particles are mobile in the upper parts of the pediment and perhaps due to the incompetency of the transportation agent a large proportion of coarse particles are left in the upper parts of the pediments.

It is also interesting to note some loss of the fraction -1ø (figs. 26 - 29) in pediment A samples. This again may support the previous assumption that the transporting agents are somewhat incompetent to transport some fractions (mostly large particles) over a distance of two kilometres or less. Sahu (1964) concluded that energy fluctuation through space and time is greater in fluvial deposition than eolian or beach deposition. The above discussion seems to support this argument (Sahu's argument) in so far as the process of transportation and deposition are concerned.

Field observation indicates that in the upper parts of the pediments (A and B), there are very few stream channels: an observation that leads to the speculation that removal may take place by overland flow rather than confined stream flow. It is probable that the inclination of 15 to 20 degrees in the upper parts is a factor in promoting swift overland flow containing particles/

particles which would favour the down-pediment movement of fine sand (3 to 4 ϕ) fraction as well as larger particles (gravel to sand fraction). In the lower part, on the other hand, (with gradients 2 to 5 degrees) the situation here may not favour more rapid movement of larger particles as the flow competency gradually diminishes down the pediment.

It seems reasonable to add here the possibility of wind, as a transporting agent, playing some part in moving some particular fraction down the pediments. This possibility is warranted for two reasons; the first reason is the fact that the average mean size of samples from pediment A is 1.3 ϕ (about the size of blown sands); the second reason is that there are some major wind blown deposits (sand dunes, fig. 15a) close to pediment A.

From the foregoing discussion on the results of the analysis of the clastic sediments of pediments A and B as well as from field observation in these selected pediments it seems justifiable to speculate the following generalizations:

1. The sedimentary characteristics of the pediment mantle (at least in the study area) are the result of several integrated factors: (a) The configuration of the landform topography, climate, the nature of rock types, and the endogenous processes. (b) The contribution of sediment by overland flow (perhaps sheet floods) and probably laterally by channelling. (c) The development of pediments and their mantles (assuming tectonic stability) by the process of weathering, erosion, transportation and deposition through space and time.

2. There are three populations that make up the pediment sediments (excluding pebbles and larger particles) with little overlap. These are, the gravel population/

population which contributes an average of 20 percent, the sand population which contributes an average of 60 percent, and the silt population which contributes an average of 20 percent (figs. 45c and 45d).

3. There is a deficiency in the size range -1 ϕ and +1 ϕ (figs. 31 - 34 and figs. 41a - 45b) at some sites. The deficiency in the fraction +1 ϕ may be a result of removal of the fraction by wind. Fuller (1962) suggested that such deficiency is caused by sorting processes such as wind. The deficiency of -1 ϕ fraction could be the result of the inability of abrasion to reduce larger particles to this size range (see P. I-162).

4. Flow velocity and grain size of a sediment are among the important factors that influence the mechanism of physical sediment transportation. According to Gilbert (1914), two fundamentally different mechanical processes are most important: suspension, in which the upward components of turbulent flow exceed the settling velocity of the particles; and traction, in which grains are driven forward by the shearing effect of the current and collide with other grains owing to the large influences of momentum and inertia. In traction, grains are moving above the bottom, but are buoyed up by eddies of turbulent flow (Bagnold, 1956). The initial energy keeping the fine-grained sediment in suspension is flow turbulence during transportation. As flow emerges from the steep hillslopes onto the plains below, this energy which keeps the sediment in suspension (depending on discharge, permeability and evaporation) no longer maintains its initial level. Under arid and/or semi-arid conditions this case is emphasized because of the brief periods of water supply, the high permeability of the surface and sub-surface materials and the high rate of evaporation. The

flow/

flow competency diminishes rapidly, so that it is reduced - in time and space - until it reaches an area in which its energy level is low enough to permit settling. The situation might explain the significant decrease in the particle sizes with distance.

5. The clastic sediments of pediments (as far as the study area is concerned) have a polymodal size frequency distribution which shows, generally, poor sorting processes, skewness to the coarse or the fine, and platykurtic distribution. The sediment properties characterize the short distance of transportation as well as the incompetency of the flow to distribute sizes normally across the pediments.

The dominant surfaces are the piedmont surfaces which form broad belts with gently concave slopes around the mountains. They have a centripetal dip of about 1.5^{o} - 6.5^{o} and descend gradually to younger deposits. They are partly a product of the remodelling and continual evolution of the Jurrasic surfaces (in Khashm Qraydān) and the Permian and older surfaces (in Wadi Al Quway'iyah) of planation. The tendency for piedmont preservation is in conformity with the morphodynamic efficiency of processes acting over this particular area which in turn will eventually, but gradually, lower the piedmonts without entirely destroying the high surfaces.

In fact, glacis, pediments and piedmont plains together constitute the planated relief. They have probably been developed under gradually fluctuating phases of arid and semi-arid climatic conditions. The resultant forms are those typical of the hot arid and semi-arid climatic areas. They have been developed in such a way that they determined the character of the landform planes or plains.

In/

In most cases distinguishing alluvial fans from pediments by field observation and/or from aerial photographs is a very difficult task. Piedmont surfaces are largely made up of depositional segments which could be either a conical or saucer shape. Some of the conical shaped segments (fans) appear actually to be veneers on pediments; hence, the appearance of a pediment may be confused with that of the fan. Several fans (and other deposits), on the other hand, may have developed over the bedrock surfaces of pediments. Such confusion led the writer to think that pediments and/or fans are stages of development of piedmont surfaces that are part of the evolution of relief of the desert landscape. This is a broad generalization that lacks the support of evidence, but it is based on the assumption that if the piedmont surfaces, which include pediments and fans, are the result of relief planation, then fans and pediments may indicate the stages of development of the planated surfaces. If this is accepted, then dating these features (fans and pediments) may lead to the dating of the planation surfaces themselves. However, as stated before, this argument is largely speculation that needs further investigation and discussion which the present work lacks at the moment.

PART TWO : THE ANALYSIS OF PEDIMENTS AND FANS

CHAPTER 6 : ALLUVIAL FANS

ALLUVIAL FANS

Definition, theories, and method

Definition

Alluvial fans are cone-shaped deposits, of mostly unconsolidated sediments (alluvium), laid down by streams where they emerge from a mountainous area onto a broad plain or meet a slower stream. The alluvium may consist of water-laid sediments. The surface forms a cone-shaped segment that radiates downslope from the apex where the stream channel emerges from the upland area. This surface gives the fan its distinctive shape (see Stone, 1967, Fairbridge, 1968 and Perrin et al., 1969b).

According to Beaty (1963) the fan shape is determined by many features, two of which are important; these are a point of drainage exit from mountains and the divergent paths of separate stream channels. Bull (1968) pointed out that fans are formed by deposition of sediment beyond the limit of mountain valleys as the result of a "change in the hydraulic geometry of flow after the stream leaves the confines of the trunk stream channels", (p. 102). If flow discharge is equal to the product of the mean depth, width, and velocity of flow, then an increase in the flow width (due to the divergence and spreading of the flow when it reaches the end of a confined channel on a fan) would be accompanied by decrease in depth and velocity. Thus, deposition near to the limits of channels where they leave the mountain front is induced, especially in areas where the surface deposits are highly permeable and the rate of evaporation is also very high.

A series of such confluent alluvial fans as described above are known as bajada (bahada) or piedmont alluvial plains. Blackwelder (1931) noted that "parallel/

"parallel to the mountain front the convexities of the component fans impart to the bajada an undulating surface" (p. 136).

Both features (fans and bajadas) are very common in the arid and semi-arid regions of the world. Most mountain ranges are bordered by sloping plains that are commonly known as coalescing alluvial fans. In some cases the upper parts of the sloping plains are erosional surfaces and cannot therefore be regarded as fans or bajadas. For such cases there is no single term in common usage to describe features that lie between the mountain front and the local base level. The term "piedmont" is one convenient term that could be used to refer to the entire area of the sloping plains where a combination of erosional and depositional segments border a mountain range. According to French writers these segments are sometimes referred to as 'glacis d'erosion' or 'glacis d'accumulation'.

Although alluvial fans are widely spread in the arid and semi-arid parts of the world, they have been studied also in other regions. Drew (1873) for example studied them in the Himalaya mountains. In the humid temperate region, Winder (1965) studied alluvial cone construction by alpine mudflows. Legget and others (1966) also studied alluvial fan formation in Canada. However, alluvial fans are another distinct feature of the arid and semi-arid landscape.

Some earlier contributions

Many Europeans of the 19th century acknowledged the relationship between erosion in the mountainous areas and deposition in the adjacent lowlands. Drew (1873) was among the earliest workers who wrote about the alluvial deposits in the humid regions.

One of the most comprehensive contributions on the alluvial fans under semi-arid conditions is the work of Gilbert (1882). He wrote "... when water leaves the margin of the rocky mass it is always united into a comparatively small/

small number of streams, and it is by these that the entire volume of detritus (from the range) is deposited. About the mouth of each gorge a symmetric heap of alluvium is produced - a conical mass of low slope - descending equally in all directions from the point of issue; and the base of each mountain exhibits a series of such alluvial cones, each with its broad base resting upon the adjacent plain or valley", (p. 184). He, in fact, indicated in generalized terms the processes by which alluvial fans are constructed.

According to the arid cycle of Davis (1905), fans are characteristic of the early stage of development (Youth) and grow larger and larger until the mountains are considerably reduced and the several originally enclosed basins have become integrated. This concept of the continuous expansion of alluvial fans is not entirely consistent. This is because fans which have been eroded to smaller depositional segments do exist in many parts of the world (see Glennie, 1970, p. 31).

Trowbridge's (1911) study of alluvial deposits is another early contribution to the understanding of fan formation. His belief was that the fan origin is clearly revealed by both surface features and internal structure.

Lawson (1915) is another contributor who introduced the term 'fanglomerate' for the alluvial fan deposits. He also drew attention to the general transition in alluvial deposits from coarse blocks near the fan apexes to finer material down the fan surface. In order to explain the presence of large particles on the lower parts of the fan surface, Lawson (1915, p.327) stated that they result from exceptional rushes of water from the mountain 'Canyon'. He also considered the importance of the extent of alluvial fan deposits.

Pack/

Pack (1923) was also involved in the problem of fan formation when he described the physiographic effects of major floods. He stressed that the accumulation of debris on alluvial fan surfaces is the result of a series of floods and debris flows. But, on the other hand, Blackwelder (1928) noted that mudflow deposits constitute the greater bulk of some alluvial fans. Thus, according to Blackwelder (1928) mudflow as an agent of deposition should be considered as an important factor in fan accumulation.

The morphology of alluvial fans in Southern California together with surface features and possible causes of changes in surface characteristics have been described in Eckis's (1928) work. His accounts of the later history of older alluvial fans and the different processes by which erosion and deposition may be brought about on fan surfaces are very useful. He also noted that fan slope decreases with increasing fan area (p. 234). This relationship between the decreasing fan slope and the increasing fan area has been stressed later by Melton (1965, p. 24).

Since then more comprehensive papers on alluvial fan geology, morphology and erosion and sedimentation processes have been published. Among those are the work of Blissenbach (1952, 1954), Beaty (1963, 1970), Bull (1960, 1963, 1964a, 1964b, 1968), Black (1964), Denny (1965, 1967), Melton (1965), Winder (1965), Legget and others (1966), Anstey (1966), Hooke (1967, 1968) and Cooke (1970a).

The literature reveals two common generalizations on alluvial fans. The first is that the deposition of sediment in fan-shaped (or cone-shaped) deposits, which are transported beyond the mountain front by local floods, is due to the inability of the flow to maintain the necessary transporting energy far beyond the limits of confined channels; that is to say to flow incompetency. The

second/

second is that alluvial fans result from adjustments in the system of erosion in the mountain range above and sedimentation in the adjacent basins below, and tends towards the establishment of an equilibrium profile between the mountain ranges and the basins (Hack, 1960). However, the problem of fan development cannot be solved by general statements. Whether a fan is to be regarded as being in dynamic equilibrium, as undergoing a cycle of development, or experiencing continuous growth (Glenie, 1970) followed by recent dissection are still matters of different opinions. According to Schumm and Lichty (1965) the foregoing statements are not opposed to each other and they may represent one or another stage of development in time. The "equilibrium concept of landscape" proposed by Hack (1960) suggested that for landforms in dynamic equilibrium, all topographic elements are eroding vertically at an equal rate with no change in time of slope form or areal arrangement of the topography.

Bull (1968) stated that the longitudinal profiles of fans (with source areas having high rates of sediment yield) are steeper than those profiles from areas with low rates of sediment supply and production. Since discharge, in general, is inversely proportional to slope, a flow of high discharge rate can transport coarse debris and smaller particles on a relatively lower slope than a flow of low discharge rate over the same slope. Thus an increase in discharge over a fan profile may cause erosion or even fan-head trenching (see Eckis, 1928), near the apex and deposition near the toe of the fan. Beaty (1963) reported masses of debris (which consists of rapidly moving mudflows) advancing downslope (after two and a half hours of heavy rain). But this flow was halted soon after the rain and the streamflows were active for about two days after the rain. The streamflow dissected the sediment laid down by debris and mud flows as well as some older deposits.

Transportation processes may play a major role in fan development especially at extreme positions, where transportation is catastrophic, such as in the case of landslides, debris flows, and mudflows, or where increasing amounts of discharge herald a transformation to fluvial erosion, as in the case of overlandflow in the form of sheetflows and confined flows such as stream flows.

It is important to note that the rate of erosion depends upon a number of factors with a considerable range of variation.. The rate of transportation, on the other hand, (although it is liable to rapid variation), depends upon a number of factors that may be regarded as of continuous and of limited range of variation. If denudation were only a matter of transportation, a great deal of diversity would be lost to the landscape. The existence of regular surfaces of landforms implies that transportation processes are capable of playing a predominant role. On low relief surfaces, such as alluvial fans, the transportation agents are dominant in fashioning a regular surface form even if the sediment transport occurs at low values of Reynold number. Emmet (1970), from field and laboratory observations, illustrated that a large volume of material can be eroded and transported by overland flow (a flow that has a relatively low Reynold number value).

Finally, it is also important to note at the end of the review on alluvial fans contribution, that although fans appear to be prominent features of the landforms in Central Saudi Arabia, they have received little attention, if any, in the literature. The great bulk of literature on alluvial fans came from other parts of the world and especially from North America.

Method and Purpose/

Method and Purpose

The primary purpose of this investigation is to obtain information on alluvial fan sediments in relation to slope and distance from the apex to the foot of the fan. This is to obtain a better understanding of the sedimentary features of the alluvial fan deposits and the geomorphological characteristics of such features in central parts of Saudi Arabia.

The investigation provided information concerning deposition and erosion which is reported later in this chapter. The relations of particle size and shape to slope, distance and depth are described. The geology of the area has been discussed in chapter 1. The results of the sediment analysis of the fan deposits are used to describe the property of these deposits. Comparison of deposits as much as four metres below the surface has been studied from the samples taken from two alluvial fans.

The study of alluvial fans is based on two kinds of evidence: (a) maps showing fan surface geomorphology and geology and (b) measurements in the field of some of the surface features of a fan together with some laboratory investigation of samples. Estimates were made about the size of material on the surface of the fan as well as the size of material excavated from the bed.

Particle/

Particle shape parameters were measured from materials on the surface of the fan rather than from material in bulk samples excavated from the base of a fan. The gravel which has been exposed on the fan surfaces are assumed to be products of the present time. Their shape measures would give information about the transporting agents and the degree of wearing during transportation. The method of sampling and the laboratory procedure as well as the discussion on the statistical methods are discussed in chapters 4 and the introduction. However, a summary on the geographical setting and the geology is given below.

Alluvial Fans in the Study Area

Geography and geology of the fan areas

The area studied here consists of a series of alluvial fans (bajada) occurring east of Jibāl (mountains) Umm ad Dabāh and west of Al'Amār (see fig. 77). The bajada area and its source is part of the Central Plateau which extends from Al Ḥijāz mountains to Ṭuwayq mountain range (see fig. 6). The bajada is in a wadi west of Jibāl Al'Amār. This segment of the wadi is a broad area of sloping alluvial plains bordered by low mountains that rise/

rise about 100 to 200 metres above the wadi bed. The foot slopes are mainly alluvial fans with very small areas of pediment.

The altitude at the base of this bajada varies between 40 to 65 metres from which the fans rise to altitudes ranging from 100 to 170 metres at their apexes. The slope angles of the fans are about 0.5 degree near the base of the longest fan to about one degree at the base of the shortest one. The fan relief is generally less than two metres, except on the upper parts where stream channels are incised about 3 - 5 metres.

The location of the names of places used throughout can be found on figures 4 and 5. For features that have no names on these figures, a text reference to their location in relation to known places is given.

The boundaries of the alluvial fans were determined from aerial photographs and the small scale topographic maps (see figs. 75 and 76).

The streams may be classified as ephemeral or intermittent and their flow is occasional when the rain falls. But some of these streams receive enough water, when it rains, to flow along their entire length for a few days after the rain. The channels, however, are always above the underground water table. Thus, the streams flow only directly in response to rainfall, when a flood flow may occur if the rainy season is sufficient. Those floods, when they occur, usually range from viscous mud to mudflow. This is because of the lack of vegetation cover which would add a sufficient supply of material to the stream load.

The average annual rainfall is 100 - 250 mm. for most of the entire area (two seasons average). Most of the rainfall occurs between December

and/

and March. The weather stations do not exist to give records on rainfall but the rainfall observed is mostly sporadic storms.

Temperatures in this area are similar to the other parts of Central Saudi Arabia in which the summer is hot and the winter is warm to mild. But temperature differences between day and night (maximum and minimum) are great. The average recorded temperature for three months in summer and three in winter is 20 - 30° C. in summer and 10 - 20° C. in winter. Prevailing winds are from the north-east. But dust storms may be formed by winds blowing from the north, west and south-west. The humidity is very low throughout most of the year.

Although the vegetation is sparse, particularly during summer, it is more luxuriant on some parts of the alluvial fans, wadi beds and flood plains (see plates 9 - 12).

<u>Morphological Characteristics</u>

Seven out of nine of the measured alluvial fans in the study area have a mean slope of 5.0° or less in which 50 percent are less than 2.5°. The maximum radii of 17 percent of the measured fans are 5.5 kilometres or less, and about 83 percent are between 1 kilometre and 2.5 kilometres. But some of the alluvial fans in the central parts of Saudi Arabia would have much greater radii than those measured (see fig. 77 and table 147).

The two fans studied are more than two kilometres (fan FXI is 2.5 km. and fan FYII is 2.2 km.) from the boulder slope to the foot of the fan where they meet the wadi bed. The width measured at the foot of the two fans is 2.0 kilometres for fan FXI and 1.5 kilometres for fan FYII.

Approximately/

Approximately seventy percent of the alluvial fans in this segment are from one to five kilometres in length and have gradients from one to five degrees. Some fans have gradients between 1.5° and 4.0° while the greatest angular measurement found is 7.5°. However, the surface angle greater than 3.5° is characteristic of the upper half of the alluvial fans.

It should be noted here that these fans coalesce and this, therefore, precluded the determination of the true width data for these features.

However, the average width varies from 0 - 5 km. to 2.5 km. Their sizes increase southward with the increase of their catchment areas. The size of the individual catchment increases from 1.25 $km.^2$ to about 14.5 $km.^2$ and the fan areas increase from 1 $km.^2$ to about 6.25 $km.^2$ These relationships point to the fact that the larger are the catchment areas, the larger fans are likely to be formed. The size of fans in the bahada segment east of Jibāl umm ad Dabāh and of their source areas are shown in figure 77. Their areal percentage relationship are shown in tables 146 and 147. The decrease in fan size are related to the spatial relations of these fans. The fans in the north receive supplies of sediments from only a small area in the adjacent hills, but the fans in the south are part of a broad bahada whose source includes a much larger catchment of Jibāl Al 'Amār range. This difference in size of the source areas results not only in a marked difference in fan sizes, but also in the sediment size distribution and the longitudinal profiles.

It is also evident from the size relationships of fans and their sources that the large fans have larger common catchment areas (see table

147/

147, and fig. 77). On figure 77, for example, fan segments b6, b7, b8 and b9 only share about 80% of the total common catchment area. Nevertheless, a relation of fan size to the source area appears to be part of the explanation of why some fans are markedly larger in size than others.

The fans studied in detail are derived from drainage basins of similar sizes. The source area of fan FXI (a6 and b6 in fig. 77, and table 147) is 6.75 km.^{2} and the fan area is 2.5 km.^{2} Fan FYII (a8 and b8 in fig. 77 and table 147), has 6.13 km.^{2} catchment area and its size is 2.25 km.^{2} Topography, lithology, climate and the tectonic environment are generally similar. In short, both fans are similar in their physical setting. Yet they have some variation in their profile slope, pebble shape and particle size distribution (see figs. 46 - 73, 111 - 140, and tables 93 - 137). This variation is probably due to the variation in the catchment area rather than to the difference in the physical environment.

The overall radial profiles of these fans are gently concave and the slopes decrease generally downslope from the apexes. The changes in some fan slopes are associated with changes that occurred in the slopes of the stream channels. Nearly all but the uppermost edge of the slopes are covered and obliterated by subsequent downslope deposition at progressively gentler gradients (see figs. 72 - 77).

Trenches have a maximum depth of 3 - 5 metres and they are terminated towards the edge of the fan segment. Relict fanhead trenches, however, can be seen on seven fans. These probably indicate that the short-term cycles of trenching and back-filling are in response to short-term climatic fluctuations, but the possibility of tectonic movements affecting stream activity cannot be entirely discounted, although no evidence for this factor can be advanced from the/

the geological literature on the area at present. The present cycle of the cutting has just started on some fans and it is less than 50 cm. in places. These cuttings would provide more information in the future about the short-term cycle of trenching in this part of the world. Until such data are obtained it can be only assumed here that such cycles do exist.

Analysis of Fan Sediments

Pebble Shape Analysis

The methods used for pebble shape determination are discussed in chapters 4 and 5. Two fans have been selected for investigation and data collection. A traverse along the maximum radius of each fan was divided into five equal parts of 500 metres interval. From each interval intersection samples were taken and measurements on larger particles were carried out in the field. The results of the shape analysis of pebbles obtained by these measurements will be discussed here and the data obtained using the computer are shown in tables 93 - 102, and figs. 111 - 140.

The frequency distribution of the shape parameters (volume, maximum projection area, sphericity, flatness and roundness) together with the moment statistics for these parameters are shown in those figures. The distribution has 20 class lengths with class intervals as follows: 15,000 units for volume, 400 units for the maximum projection area, 0.05 units for sphericity, 0.30 units for flatness, and 50 units for roundness. The class intervals were obtained by dividing the upper bound for the largest particles by the frequency length which are twenty equal parts. The maximum/

maximum value for volume is 300,000, for maximum projection area is 8,000, for sphericity is 1.0, for flatness is 6.0, and for roundness is 1,000.

<u>Roundness</u> The average of the mean roundness of pebbles from each site on both fans seems to increase rapidly as we travel down fans from the apexes (tables 103 - 105). The roundness increases from 231.81 at a distance of 200 metres from the apex of fan FYII to 408.98 at a distance of 2200 metres from the apex of the same fan. At fan FXI the roundness increases from 217.38 at a distance of 200 metres from the apex to 344.41 at a distance of 2200 metres from the apex of the same fan. Applying the t-test for the significance of roundness increase with distance down the fan slope, the result is that the increase in pebble roundness is extremely significant at 0.99 level. Referring to the t tables (Fisher and Yates, 1948; Ankin and Colton, 1950) indicates that for V = 4, t 0.99 = 3.75 and a value of 4.51 obtained (from the average roundness of pebbles from fan FXI) is significant at this level. Therefore we accept the hypothesis that there is a significant increase in roundness of pebbles with distance. For fan FYII we obtained the value of 5.30 which is significant at P_0 0.1 level. Therefore the increase in roundness of pebbles with distance is significant. The standard deviation ranges from 90.49 at a distance of 200 m. from the apex of fan FXI to 153.28 at a distance of 2200 m. from the apex of the same fan (see table 103). For roundness of pebbles from fan FYII, the standard deviation ranges from 80.18 at a distance of 220 m. from the/

the apex to 154.58 at 2200 m. from the apex (see table 105). The variance ratio test shows significant variability.

These results indicate a similar increase of pebble roundness with distance, among both the pediment samples and the fan samples. Therefore, the explanation offered in the discussion of pediment pebble-shape analysis could be warranted also here (see p.I-126). The detailed analysis of the roundness variation. however, suggests that the variability in roundness between pebbles from all sites is due to the different kinds of lithology in the igneous and metamorphic groups of the parent rocks. Comparing the mean roundness of pebbles in each site interval on the traverse with the next one shows no great difference in the roundness increase. But when the average of the means of the first two sites on the traverse (which are at 200 and 700 m. from the apex) are compared with the last two sites (which are at 1700 m. and 2200 m. from the apex), the difference shows a significant increase.

Blissenbach (1954) believes that the high degree of roundness of pebbles which he found in fan gravel was not achieved on an alluvial fan but in a flood plain environment. "Later faulting (according to him) brought these gravels into a position where they could be redeposited as fan gravel", (p. 184). As tables 103 - 105 indicate no high degree of roundness in the pebbles derived from fan FXI and FYII, it could be argued that the degree of roundness of fan pebbles may not be very high.

Tables 99 - 102 show the roundness of every individual pebble collected from the two fans. They also show other shape parameters for these pebbles./

pebbles. Considering these pebbles, there is no indication that the roundness decreases according to the increase of the long axes (L axis) of the pebbles. The functional relationship is that the roundness would increase if the difference between the long axes (L) and the smallest radius of curvature decreases. This, in fact, supports the assumption that the corners of pebbles would be rounded more with longer distance of transportation. Waddle (1932, p. 446) and Pettijohn (1957, p. 57) stated that roundness is geometrically independent of shape. This indicates that a cylinder capped with hemispheres has roundness unity like a sphere. A sphere has uniform radius of curvature over its entire surface but the other does not, nor does the radius vary smoothly from point to point.

<u>Sphericity</u> Tables 99 - 102 and figures 111 - 140 show some changes of sphericity with distance in both fans. At 200 m. from the apex of fan FXI the mean sphericity is 0.65 which increases, but not rapidly, to 0.78 at 2200 m. down the slope at the fan edge.

Allen (1948, p. 312, table 1) and Sneed and Folk (1958, p. 141) show that sphericity is a function of size. The results of the sphericity as shown in tables 93 - 102 are variables and do not show any functional changes with size. This may be due to the fact that the samples here were not confined to limited size grade (say between 20 mm. and 70 mm.) which have been suggested by Sneed and Folk (1958, p. 136). However, many authors have found no significant change of sphericity with size (see Krumbien, 1942, p. 1383, Carroll, 1951, and Blissenbach 1954, p. 183).

The/

The variation of the mean sphericity values and the variation of the standard deviation values with distance are shown in figures 111, 114, 117, 120, 123, 126, 129, 132, 135 and 138. Although Bluck (1964, p. 397, fig. 5) has shown that there is an increase in the standard deviation along the fan head trench and a decline towards the base of the fan, this trend cannot be traced in either locality (see p. I-111).

Comparing the sphericity of pebbles derived on pediments from limestone parent material (compare tables 26 and 27 with 29 and 31) and the sphericity of pebbles derived from metamorphic and igneous parent materials, it appears to be the mean value of sphericity does not change significantly in the case of the limestone parent rocks. But the pebble sphericity on both fans shows some increase in sphericity with distance.

The relationship between sphericity and distance could be shown better if all pebbles have similar lithology. The argument presented in chapter 5 on the pebble sphericity in relation to distance is also applied here. However, there is no significant change in pebble sphericity as related to distance in the fans studied. Blissenbach (1954) also found no marked change in the sphericity of fan particles. Any change, according to him, is expected only if there is a change in composition or facies of the fan deposits (p. 184).

<u>Form</u> Tables 93 - 102 show the form class for each pebble measured in both fan localities with a total of 1000 pebbles. The frequency percent of the form class in relation to distance is shown in table 107. Although the comparison between each site does not reveal much information, the overall/

overall percentage, however, indicates that more than 30% of the pebbles from both fans lies in the bladed categories (that is to say bladed, very bladed and compact bladed). About 21% of the total pebbles are from the elongated categories, and 21% are from the platy categories. The rest of the pebbles are compact in their form. This signifies the expectation that due to the lithological characteristics of the morphometric and igneous pebbles, a large number would fall under the bladed categories. The concentration of pebbles in a particular form class, as suggested before (compare table 32 with table 107) is not as restricted to the type of rock so much as to the behaviour of the agent of transportation (see also Sneed and Folk, 1958, p. 146).

Bluck (1964, p. 397, figs. 6 - 9) shows some systematic variation in the frequency of pebble form class (shape, according to him). He also found a general increase in the blade forms in the fan head channel, a decline on the fan proper and slight increase towards the base of the fan. This trend, however, is not the case of both localities in the study area. The bladed group of pebbles here, in fact, are variables in fan FXI while they show clearly a general decrease down the slope in fan FYII. However, certain groups are consistent. Such as the elongated group has a general decrease in number as with distance.

Particle Size Analysis

The particles above 4 mm. and below 16 mm. in diameter are treated separately for size analysis. Their weight percent in relation to smaller particles is shown in figures 56 - 71. Figures 56 - 71 also show/

show the distribution of these particles in three major class intervals; finer than 8 mm, 12 mm and 16 mm.

The percentage of the particles above 4 mm. and below 16 mm. in diameter decreases markedly with distance and depth in the studied fans. The percentage of surface material on fan FXI, of the range size 4 - 16 mm., decreases from 77.47% near the apex to 24.39% at the edge of the fan. For the same range size, the percentage of surface material on fan FYII also decreases from 69.40% near the apex to 15.86% near the edge of the fan. Both cases suggest that the amount of larger particles than 4 mm. of surface material increases to more than three times near the fan head.

At 2 m. depth, particles larger than 4 mm. and smaller than 16 mm. decrease in percent from 48.90 at 200 m. site from the apex of fan FXI to 15.64 a distance about 2200 m. from the apex. The same range of particle size for the same depth site in fan FYII decreases from 45.31% at 200 m. site to 6.35% The average percentage increase for both fans at 2 m. depth site towards the fan head is more than twice.

For 4 m. depth sites, the same particle size range decreases from 45.61% at 200 m. site on fan FXI to 10.62% at 2200 m. site, and from 40.93% at 200 m. site on fan FYII to 4.92% at 2200 m. site. At this site (4 m. depth) the average percentage increase of particles larger than 4 mm. towards the fan head is more than five times.

The decrease in the amount of particles larger than 4 mm. both on the fan surfaces and at depth, with distance from the mountain front is the result of the decrease in flow competency. Stream discharge is by definition equal to the product of the mean depth, width, and velocity of flow. For a given discharge, increase in width of flow is accompanied by decrease in depth and velocity/

velocity. When a stream reaches the end of a channel on a fan it therefore spreads out and thus causes deposition.

The analysis of large particles ($>$ 4 mm.) of the alluvial fans clastic sediments shows at least two groups - perhaps stages - of deposition. The first is a series of coarse and fine particles all of which decrease in size away from the source with a high rate of decrease. The second is composed of fragments all of which also decrease in size but with a lower rate of decrease.

For particles finer than 4 mm., the cumulative frequency distribution of particle size, which were analysed by sieving and pipette methods, are shown in figures 46 - 55. The methods for sampling and laboratory procedures are discussed in chapter 4 and the introduction. However, the size analysis is related to distance and depth. The results of the moment statistics are grouped accordingly and are shown in tables 108 - 137. The sequence of these tables represent the sequence of depth on each distance interval. That is to say that at each 500 m. interval down fans there are three samples to represent surface materials, materials at 2 m. depth, and materials at 4 m. depth respectively.

Mean Size The average of the mean sizes of samples from fan FXI is about 1.68 phi with average standard deviation of 1.78 phi. This means that the average size of fan FXI is in the range of medium to fine sand. Fan FYII has finer average mean size than fan FXI. It lies within the range of fine sand with average mean size of 2.67 phi and standard deviation of 1.83 phi. This is due to the fact that fan FYII has both coarser and finer materials while fan FXI seems to have a general size trend of medium sands. However/

However, the detailed analysis of the mean sizes in relation to distance shows a general trend that particle sizes decrease with distance in both localities. The mean sizes of fan FXI decreases from 0.98 phi with standard deviation of 1.77 phi of surface material at a distance of 200 m. to 2.75 phi with standard deviation of 1.45 phi of surface material at 2200 m. On fan FYII the mean size decreases from -0.005 phi with standard deviation of 2.06 phi for surface materials at 200 m. to 3.97 phi with standard deviation of 1.88 phi at 2200 m. That is to say that from both fans it is evident that particle sizes decrease with distance and there are more fine materials to be found as we travel down fans. Krumbein (1937) stated that a close relationship between particle size and surface slope distribution seems obvious. Blissenbach (1952) believes that he has obtained field evidence to support the relationship between slope and size on alluvial fans. Figures 61 - 63, and 69 - 71 shows the relationship between size and slope on both fans (see also tables 144 and 145). The overall change in the slope with change in the size of bed and surface material indicates a trend for slope to increase as the size increases. This relationship seems to explain, partly, why some fans are concave in their longitudinal profiles.

<u>Sorting</u> The average sorting of fan FXI is $\sigma 1 = 1.78$ phi and the S-range 1.43 - 2.37 phi while fan FYII average sorting is $\sigma 2 = 1.83$ phi and the S-range 1.02 - 2.81 phi, which indicates that the sediments are moderately to poorly sorted. Fan FYII has about twice spread in grain size than fan/

fan FXI. The standard deviation reflects the complex mixing of sediments in fan FYII and the poorly sorted material in this fan is expected because of the 2.81 phi and 2.72 phi high that is included in this fan. However, this kind of sorting also reflects the fluvial detritus characteristics which, unlike eolian deposits, tend to be generally ill-sorted. The difference in sorting in both fans indicates that the sediments in fan FXI have been subject to more frequency runoff than those in fan FYII. This is due to the fact that fan FXI has larger drainage basin area than fan FYII (see fig. 77).

Skewness More than 70% of the samples from fan FYII are positively skewed while more than 50% of the samples from fan FXI are negatively skewed. Fan FYII also contains greater positive skewness (+1.57) as opposed to fan FXI (+0.29).

The average skewness of samples from fan FXI is SK = -0.033 phi with S-range SK = +0.29 phi to -0.341 phi. Fan FYII average skewness is +0.236 phi but more scattered with S-range SK = +1.569 phi to -0.462 phi. Half of the negatively skewed samples of fan FXI are more than -0.1 phi but fan FYII has a sample more negatively skewed than in any other samples (-0.462). Fan FYII samples, however, tend to be more unimodal than those from fan FXI which are more likely polymodal.

Although a precise definition of environment is difficult to construct, the sign of skewness can be related to energy and therefore to the environment. Mason and Folk (1958) differentiate beach sediments as negatively skewed from dune and eolian flat sediments which are positively skewed. Friedman (1961) also concluded that for the most part dune sands are positively skewed whereas beach sands are usually negatively skewed.

Where winnowing is the dominant force the energy is high. Hence the beach sediments are negatively skewed. Areas where energy levels are low are characterized/

characterized by no particular dominance of either positive or negative skewness.

The wide range of skewness values of the fan sediments are thus indicative of fluctuation in energy levels. However, the average positive skewness of samples from fan FYII also indicates that the energy levels are lower than those of fan FXI. This could be related to the fact that fan FXI has a larger drainage area than fan FYII.

Kurtosis

Fan FXI average kurtosis K = +0.77 phi and the S-range is K = +2.57 to -0.27. Transformed kurtosis values are obtained by the following:

$$K_{\phi} = K / (K + 1)$$

if I = 0.50 the curve is normal, but for values higher it is leptokurtic and for values lower it is platykurtic. The average K_{ϕ} of the samples from fan FXI is $K_{\phi} = K / (K + 1) = 0.7684 / (0.7684 + 1) = 0.43$ which is to be platykurtic.

Fan FYII, however, has an average kurtosis K = 1.31 and the S=range is K = +11.87 to -0.86. The samples here are leptokurtic ones having $K_{\phi} = 0.57$. But considering all samples from both fans (which average K = +1.04) are mesokurtic averaging about $K_{\phi} = 0.50$.

If we consider the assumption that the kurtosis is sufficiently sensitive to the presence or absence of fine sediment, then it can explain the difference/

difference between the two fan sediments. Not only that but it also explains the difference in the mean size, skewness and sorting. However, one can draw attention to the fact that although the fan sediments studied here were built-up in an alluvial medium, it has not developed a large amount of clay.

The contrast in sorting indicates that the poorly sorted material may have been carried in suspension, and the more sorted deposits may have been transported predominantly as bed load. The sorting index obtained from the samples of the studied fans suggests that the deposits are of mudflows and sheet floods. The change in size from the apex to the toe of a fan is greater between each site than the overall mean size. This is due to the degree of intensity of processes which may have been varied. However, erosion and sedimentation seems to be the dominant factors of processes in the fan deposits. The differences in size shown by the samples could be related to the differences in the amount and frequency of precipitation and in weathering on adjacent slopes.

Analysis of variance

This has been performed in the same manner as has been mentioned in chapter 5. That is to say that the experimental design for the analysis of variance was devised to show the source of variation between the sediment means and standard deviation in relation to distance and depth. Tables 138 - 141 show the computation for the analysis of variance as well as the experimental design, while tables 142 - 143 show the summary of the computation. The factors/

factors involved are: a which has a_1, ----- a_i level and denotes the depth, and factor B which has B_a, ----- B_j level and denotes the distance on the fan surface. The effect of the depth and distance on the particle size was the reason for this factorial design. The test of significance for the F ratio obtained by the analysis of variance shown in tables 142 - 143, for the means of samples from fan FXI indicates that the variation in the sample means among the distance factor (a_i, table 138) is significant at Fo-10 points. In this table the F ratio obtained is 3.452, and from the F distribution tables (see Kreyszig, 1970, appendix 4, tables 9a, 9b, pp. 455 - 458, Rickmers and Todd, 1967, table A4, pp. 557 - 562) we found the value of Fo-10 4, 8 = 2.81. This having 4 degrees of freedom (5 - 1 = 4) for V_1 and 8 degrees of freedom (3 - 1) (5 - 1) = 8 for V_2, the F ratio obtained is beyond that value in Fo-10, 4, 8. If the hypothesis is that the distance would not be the source of variation in the means of the grain sizes of the samples from fan FXI, we therefore reject this assumption. It follows that for this particular case the mean values are not equal and that the distance has some effects on the grain size means. The depth on the other hand having the F ratio = 1.6593 (tables 142 - 143) and referring to the F distribution tables the value Fo-10, 2, 8 is = 3.11. Thus the F ratio here is not significant. We therefore reject the hypothesis that the depth has some effects on the sample means of fan FXI. It follows that we accept the hypothesis that the sample means here are but equal and the depth does not act as the source of variation. The same conclusion could be stated for the standard deviations of the samples from fan FXI

(see/

(see table 134). Here we have again the source of variation among the distance factor (a_i) rather than the depth factor (B_j). Considering fan FYII (see tables 140 - 143, for the analysis of variance) the F test shows that there is a strong significance on the F ratio for both factors; distance, and depth at all levels. That is to say that the source of variation is between the depth factors as well as among the distance factors. Accordingly, we reject here, the assumption that the depth has no effect on the sample means. We also reject the assumption that the distance has no effect here. Thus, we accept the hypotheses that the mean values of the sample means form fan FYII are not equal because both factors, the depth (B) and the distance (a) have affected the means of the grain size distribution.

Overland flow (such as sheet flow) and confined flows (channel flow) differ considerably in their ability to erode and transport sediments. Due to the small amount of tractive force and the large amount of resistance, overland flows have relatively low energy levels. Channel flows or stream flows, on the other hand, are confined to smaller areas of resistance and a larger traction force is exerted. Thus, confined flows are more competent to move sediments, especially coarse sediment over a given distance than overland flows.

The relationships of particle size to distance of flow are in accord with ideas of competence. For a given distance, flows with high energy levels are able to transport larger amounts of coarse and fine particles than those with low energy levels. Thus, it could be argued that the size/distance relationship may reflect flow energy, and hence competency. The significant decrease of particle size down the fan profiles (FXI and FYII), therefore, indicates the incompetency of flow to move all particles, equally, across the fans. Hence, the/

possibility of overland flow (such as sheet flow) is offered. However, this point is discussed further in the following section (graphic interpretation).

The comparisons of the results from the size/distance analyses of pediments (A and B, tables 83 - 92), with the results of size/distance analyses of fans (FXI and FYII, tables 138 - 143), indicate similarities in the flow energy levels and the environment of deposition that can hardly be overlooked. These similarities are discussed further in the concluding chapter.

Graphic Interpretation: The curves showing the size frequency distributions of clastic sediments (< 4 mm.) on alluvial fans are plotted on arithmetic probability papers in phi scale (figs. 46 - 55). The size means of the total samples are shown in figures 55a. Examination of the curves of the average mean sizes (fig. 55a) indicates that all samples from alluvial fans (FXI and FYII) could be described reasonably by two log-normal grain size populations either mixed together in various proportions or separate with little overlap. These populations are the gravel/sand population with a median between 0 and 1.5 phi, and the sand/silt population with a median between 2 and 4 phi. The medians determined from the curves (figs. 55a) will lie somewhere in between the two parents in such a way that their positions are determined by the percentage contribution of each parent to the total population.

Under conditions of deposition where relatively high energy flow conditions prevail, little of the sand/silt population will be deposited and thus the median may be an indicator of the energy of the depositional environment.

Considering the curves (200 m. and 700 m. sites, fig. 55a), the situation here is that there is very little of the fine sediments in these curves. This situation indicates that the energy level is relatively high. This situation has/

has also been indicated by the results of the analysis of the moment statistics discussed earlier (p. I-154).

Several authors have recognized bimodality of size frequency distribution in the gravel/sand population. Trowbridge and Shepard (1932) attempted to account for the lack of material in the intermediate size range within bimodal samples, by suggesting two widely differing energy levels in the environment of deposition. The frequency distributions in the present study (figs. 46 - 55) are also showing bimodality, and signifying that the modal diameter values consist of dual population; that is there are two averaged modes present. A primary mode which constitutes the dominant population (sand) and a secondary mode which varies according to positions on the longitudinal profiles of the fans. The secondary mode on the upper fan is the gravel fraction and that on the lower fan is the silt fraction. This means that the variation in sorting may be the result of mixing of two modes in different proportions.

Fuller's (1962) example of two component curves is similar to the curves plotted in figures 45c, 45d, and 55a. He examined the possibilities for the deficiency in the 2 phi fraction: (1) that the inflection is due to a change of hydrodynamic processes, or (2) the 2 phi fraction was selectively removed by wind action. A third possibility could be added here; it is that the samples are produced by simple mixing of two populations having unlike variance. This might be brought about as Pettijohn (1957) has suggested, by the processes of rock disintegration which may yield products of varying grain size and produce more of certain sizes and less of others (p.50). Although it is likely either factor of the above mentioned could have caused deficiency, the evidence for wind action in the study area suggests that selective removal by wind may have lead to the deficiency of certain size fractions.

Morphological/

Morphological characteristics of fans

The metamorphic rocks of Jibāl umm ad Dabāh produced a fine to medium grained material that has been deposited by the west flowing streams. The deposition has produced a broad bajada (about 20 km. long and 2.8 km. wide) that slopes gently towards the east where it meets the wadi running south/northeast. The bajada is underlain by an unknown thickness of deposits, largely boulders, pebbles, sand and silt (see plates 11 - 16). Both fans studied are covered with medium to small size pebbles and has a luxuriant growth of desert shrubs.

Fan FYII has a steeper slope at the upper parts and a gentler at the lower parts than fan FXI. Both fans are fashioned by many small and discontinuous washes only two metres or less in depth and width (see plate 15). The longitudinal profile of fan FYII shows a pronounced concavity and the material underlying it decreases more in size downslope than fan FXI. However, near the apex of both fans, the wash is more incised and the slopes are more steep than near the toe of the fans segment. The gravels beneath the fans (4 m. depth) suggest that they are derived from the same source area. The depositional segment area of the fans is about the same (2.4 square km.).

The grain size decreases and the upward concavity of the longitudinal profile of some fans is probably related to the spatial relation of that fan. The upper parts of the fan may receive discharge from the adjacent hills, while the lower part would have other discharges coming from larger source areas and receive more sediment compared with the lower parts of other fans. This difference in the size of the source area between the two localities results in a difference in slope and in size of material. That is to say that there is a more marked decrease in slope and in size of material in one fan than in the/

the other.

More recent fans on the bajada segment could be inspected on plates 11 and 12. The plates show that there is an apex of a fan-shaped area that extends to the edge of an older fan. The suggestion is that some time ago the streams in the older fan-building washes were diverted from their places into new channels. The streams in the new channels cut down through the old segments which have been since transformed into the modern fans.

The size of the material on the surface of the fan washes ranges from boulders at the upper part to cobbles and pebbles downslope and to gravels, sands and silts further down. But the amount of fine material is small (see tables 93 - 137, and figures 56 - 71, for comparison). In some parts the changes in size from one site to the next are pronounced, but the overall change of the size of the surface material from apex to toe is more generally found (see the analysis of variance in tables 138 - 143).

The overall size of any fan is a function of its drainage basin features such as size, slope, rainfall, the parent material and its characteristics, and the erodability of such rocks. Thus, until such study has been made as to cover all the aspects involved, there is very little to say about the relationship between fan size and slope. However, so far as the fans studied are concerned, the general statement by Blackwelder (1931) seems to be true here. Blackwelder stated "..... large deep canyons have broad fans of low gradient; short ravines have small steeply sloping fans" (p. 136).

The general trend of the radial profiles of the fans studied are gently concave upwards. This is supported by the reports of Trowbridge (1911, p. 714) Krumbein/

Krumbein (1937, pp. 588-590), and Blissenbach (1954, p. 176). The radii of a fan, however, is restricted by adjacent fans and by stream deposits and for that reason there could be some fan segments which do not decrease gradually away from the mountain fronts.

There is a general relation between the streams and the fan gradient. The steep fans that form at the mouth of a canyon would have steep longitudinal profiles, and the gently sloping fans that form at the mouth of a wadi would have gentle longitudinal profiles. Kesseli and Beaty (1959) have also noted this general relation (see p. 19).

Finally, the understanding of the formation of alluvial fans requires recognition of changes of processes through time and the inter-relationship between all factors involved. Since there is a lack of information on the climatic changes which may have occurred throughout the area, a most reasonable explanation on the fan morphology would not be complete. Until such work has been done, which would be in the near future, there has been very little discussion on the theory of alluvial fan formation.

CONCLUSIONS

CONCLUSIONS

Geomorphological mapping

The types of maps produced are designed to give a detailed account of some aspects of the geomorphology of the study area with emphasis on lithological background, structural influences, types of landforms, chronology of the solid rocks with some reference to Quaternary deposits, and geomorphological evolution. Such a task is very complicated especially when the area to be mapped is as large as the study area. However, the scheme employed must be modified to economise on time and minimise effort.

Generalization of the content of the maps has been found necessary during the transition from large scale maps to medium scale maps. This generalization, however, did not exclude any of the elements of the geomorphological maps: the genesis, morphology, and the morphometry. Admittedly, on the medium scale maps, only large subdivisions of the relief type could be mapped. Thus, morphological generalization has been carried out, when necessary, in order to solve the cartographic problems such as the size of lines and symbols in relation to the mapping scale.

It has been found very rewarding and useful to apply the method of aerial photographic interpretation. It was possible to map and classify the landforms with very limited field surveying. But when the questions of definition, recognition, and evolution are involved, then comprehensive field and laboratory investigations and analysis are required.

However, the maps illustrate the morphological aspects of desert landforms/

landforms as they exist in parts of Central Saudi Arabia. These features are recognizable on aerial photographs except those which have similar characteristics that could be easily confused. Most areas of accumulation are easily identified. These features are sand dunes, sand sheets, gravel plains, and alluvial fans and terraces. Pediments and glacis, however, are more difficult to define, identify, and map. It has been found that most pediments of the study area are of a type that could be easily regarded as glacis or terraces. It is obvious that when pediments are buried it would be impossible to distinguish them from these related forms from aerial photographs. This is because such recognition needs an investigation through the alluvial cover to the bedrock beneath the surface.

Detailed erosion characteristics, such as drainage density and the magnitude and relative uniformity of slopes could be used in the field of geomorphological mapping. Furthermore, sharply defined linear or gently curved scarps and breaks in erosion or dissection characteristics could also be used in the determination of the form characteristics in landform units mapping.

Lithologic control has a special emphasis which is evidenced from the difference in relief development between the southern parts and the rest of the study area. The contact between the basement complex rocks and the sedimentary outcrops resulted in the development of landform systems that show the effect of lithological control. The systems include surfaces of denudation and degradation. Such surfaces are inselbergs and other residual/

residual hills, mountain massifs, gravel plains, piedmont surfaces covered with coarse detritus, bahadas, plateaux and cuestas, and terraces. Inspection of geomorphological maps reveals obvious differences between the drainage patterns. The uplands of the south west (Al Quway'iyah/Al Amār area) show inumerable stream channels most of which are either dead wadis filled with sand or embayments also filled with sand. On the other hand most of the area between Al Quway'iyah and Qraydān shows that the drainageways are sparse (fig. 14a), while the uplands are also relatively dissected (fig. 15a). The contributing drainage areas of individual stream segments outlined in the maps seem to have a variety of shapes. Some are oval and a number are sub-rectangular while others are almost circular.

The absence of vegetation cover makes every detail of the landforms appear clearly in the photographs. This fact may assist in other aspects of photographic interpretation, but certainly adds to the difficulty of stream order construction. Although stream numbers, length, and order are very important parameters, the difficulty in distinguishing dry channels from passes and other similar bodies (which are also filled with sand) eliminated such attempts being carried out by purely photographic method. Added to this is the problem that most streams appear to be joined together and the distinction between sub-drainage areas becomes also impossible. Because of the above mentioned problems as well as the fact that there is no universally accepted method for drainage order construction, quantitative measurements have not been attempted in this work. It is also important to add/

add here that there are no adequate topographic maps to assist in solving the problems.

The drainage network is dry most, if not all, the time and most rills, embayments, and passes are filled with sand. The identification of channel features is not always clear from the photographs; however, the following generalizations are obtained qualitatively by photographic interpretation.

The drainage pattern in the southern parts (figs. 12a and 13a) indicates that the tributaries of the main wadis branch and rebranch freely in all directions. Although resembling a dendritic or treelike pattern in some respects, the infilling of passes as well as channels by sand gives the impression of almost complete reticulation of the network. Without detailed topographic maps it is not possible to resolve some patterns into separate drainage basins without great difficulty. The granite areas exhibit a fine-textured reticulated dendritic pattern with repetitious curving tributaries outlining circular or dome like hills. Where folded or dipping rocks occur (fig. 12a and 13a) parallel patterns are comprised of channels flowing side by side in the direction of the regional slope. Subrectangular patterns developed where metamorphic rocks prevailed. The patterns are sometimes extremely regular and have recognizable short gullies that are locally parallel. The absence of an integrated drainage system in other parts of the study area (fig. 14a) indicates the highly permeable rocks (such as shale, limestone, and sand/

sand dunes) which absorb runoff. The water discharge may not be enough, at present, for the establishment of a drainage pattern in the low relief areas. However, some drainage patterns are recognizable in the north part of the study area (fig. 15a).

The development of pediments and fans

Although terminology used for defining and describing desert landforms are widely accepted among geomorphologists, terms such as pediments and glacis are still controversial and cause confusion. Whether pediments are related to a particular climatic zone or are developed world wide is still a major controversy. While some authors believe that pediments are related to particular lithological conditions, others consider that lithology has no major control over the development of pediments. Many geomorphologists consider pediments as major erosional features of the deserts in which the central problem of arid land geomorphology could be investigated.

However, it has been found that pediments in the study area occupy less than 2% of the total area. This fact indicates that pediments, here at least, are not the current major features of this part of the world. Where they exist more widely they are buried under variable thicknesses of alluvium. Thus, pediments may have been major features, but certainly, under different climatic conditions. Depositional surfaces rather than erosional surfaces are widely distributed in the study area (more than 85% of the total area are depositional surfaces). Cooke (1970) found that the percentage of the total area of the Western Mojave Desert covered by pediments is only 6.7% of the landform areas (see Cooke, 1970, table 2, p. 32). Further investigation is needed before comparisons can be made with the average percentages of pediment areas in other landform areas, other parts of Saudi Arabia/

Arabia, and other parts of the desert world.

Other characteristics of pediments do occur. Such characteristics are the sharp break of slope between the pediment surfaces and the mountain fronts, the smooth longitudinal profiles of the pediment surfaces, the low gradient, and the very coarse surface material (see figs. 25 and 25a). The following table summarizes the major characteristics of fans and pediments in Central Saudi Arabia.

	Pediment	Fans
average length of longitudinal profiles	1 - 2 km.	2 - 5 km.
average sediment depth	1 - 2 m. (buried 4.5 m.)	5 - 8 m.
average slopes		
max.	8°	10°
min.	1.5°	0.30'
average pebble		
size	-6 phi	-3.5 phi
roundness	270/1000	280/1000
sphericity	0.65/1.0	0.70/1.0
form class	bladed to platy	bladed to compact
average grain		
size (finer than 4 mm.)	1.5 phi	2.5 phi
sorting	poor	very poor
stratification	unstratified	poor to moderately stratified

If we accept the definition of a pediment as 'an erosion surface cut out of bedrocks, and carrying a thin alluvial cover, that slopes gently to a playa, plain, or any local base level,' then the pediments investigated

(which/

(which have between 4 and 5 metres of alluvial cover) are not proper pediments. Here comes the confusion because even the French term 'glacis' has been used to define features similar to pediments but which are developed in soft rocks. It has been found that beneath the alluvial cover in the pediments studied lies an erosion surface cut out of hard bedrocks. Mensching (1973) stated in his summary that "glacis sediments often cover the pediment basement which underlies them at different depths according to the geological structure", (p. 134). Busche (1972), however suggested that "younger alluvial fans - under semi-arid conditions - have buried the relicts of older pediments, that are best presented near the mountain front, thus giving rise to the misconception of the downward-bending sub-alluvial bench", (pp. 21 - 22). The pediments of the study area are not covered with younger alluvial fans as found by Busche (1972) in the Tibesti-Gebirge of Tchad, because there is no field evidence of fan building on the pediment surfaces. The sediment resembles rather 'glacis' deposits that may have buried the older surfaces - such situations do exist elsewhere, as shown by Mensching (1973).

Field investigations indicate that the pediments (A and B) are covered by deposits of varying thickness depending on the rate of deposition and its duration. According to Schumm and Lichty (1965), landform development is a function of time and space. As the time and/or the space limits change "the factors that determine the character of landform can be either dependent or independent variables", (p. 110). During the 'cyclic time' span of Schumm and Lichty (1965), the survival of the alluvial cover of the pediments, the survival of the pediments themselves, or the survival of the alluvial fans is a function of/

of the independent variables (time, geology, initial relief, and climate). Time here, according to Schumm and Lichty (1965), is perhaps the most important independent variable and, according to them, "...it determines the accomplishments of the erosional agents and, therefore, the progressive changes in the morphology of the system", (p. 113).

Considering all the variables are constant except time, the relief and mass of a drainage system, accordingly, will decrease. Such changes would lead to changes of the dependent variables such as morphology and hydrology (see Schumm and Lichty, 1965). However, the changes during the 'cyclic time' may be seen as a series of fluctuations within the 'dynamic equilibrium' or a 'steady state'. Thus, a pediment or a fan profile may be graded but as Schumm and Lichty (1965) pointed out "the entire system cannot be graded because of the progressive reduction of relief or volume of the system above base level, which occurs through export of sediments from the system", (p. 114). While the concept of cyclic time can be applied to entire systems covering large areas, what Schumm and Lichty (1965) regard as short periods of 'graded time', during which equilibrium conditions may persist, can only be applied to components of the systems covering relatively small areas.

The foregoing arguments indicate that although fans and pediments may be regarded at present as in a dynamic equilibrium, they may show signs of fluctuation during the "graded time". It is also possible that although pediments and fans at present show no progressive changes, during long periods they may be undergoing progressive changes. During a dynamic equilibrium state the progress of fan and pediment development appears to be static, but their drainage basins undergo progressive changes which are probably of small magnitude.

One/

One must consider here the possibility that some variables such as hydrodynamic components may become significant during the short span of time and therefore may change some parts of the system. If pediment alluvium is considered under the concept of the 'graded time span' it may be explained with regard to short term changes in the hydrologic, geologic, and/or climatic variables (see Schumm and Lichty, 1965, table 1, p. 112). In terms of such an argument, the pediment covers may be considered as transient during the downwearing associated with systems equilibria accompanying variation in climate or geology. Alternatively, the surface sediment can be incorporated as a dependent variable within a steady state model of the present pediment system.

Mensching (1973) found that "the morphogenesis of the pediments generally began earlier than that of the glacis", (p. 134). He also stated that "the arid conditions which have been dominant in all dry regions since the young Tertiary have played a decisive role in forming the pediments", (p. 134). According to him (1970, p.2) "under predominant arid - morphodynamic conditions - strong desiccation of the soil and short tropical rainfall with effective plain forming - piedmont plains of a 20 - 50 m. deeper level with pediments and glacis have been formed". He (1973, p. 134) also stated that "glacis do not date back in their first morphogenetic phases to the periods of Tertiary deep weathering". As indicated earlier, the survival of the pediments alluvial cover during periods of 'graded time' leads to the view that these pediments are buried at present. Buried pediments have been found in other deserts (see Mensching, 1970, and 1973, and Busche, 1972). The present stage of development on pediment surfaces indicates that the climatic phase tends/

tends to be more arid than during the formation of glacis over the pediment surfaces. This is supported by the presence of some small barchan dunes (see figs. 15a and 15b) on the surface of pediment A, and by the absence of fine materials from the surface of the alluvial cover (see tables 33, 40, 43, 44, 55, 59, 64, 70, 74, 78, and figs. 13, 41a, 41b).

According to Langbein and Schumm's (1958) curve, the maximum sediment yield (peak) occurs under semi-arid conditions (at about 300 mm. mean annual precipitation). Wilson (1969), however, found a second peak of sediment yield at about 762 mm. mean annual precipitation (under sub-humid conditions). According to both curves, semi-arid and/or sub-humid areas have sediment yields higher than arid and humid areas. Considering that pediment formation is favourable under sub-humid or semi-arid conditions, and considering that pediments are older than fans and glacis, and with regard to both curves (Langbein and Schumm, 1958, and Wilson, 1973), the following speculations may be warranted here:

A. During an earlier period (Tertiary?) the relief has been shaped by processes of denudation.- pediments were formed as the slopes retreated during relief reduction and weathering took place. The rainfall is assumed to be seasonal and the mean annual precipitation may have reached 1,000 mm. Sediment yield according to the above mentioned curves is relatively low but sediments may travel beyond the piedmont zones.

B. Unknown periods between A and C during which the mean annual precipitation is assumed to have fluctuated between 1,000 mm. and 700 mm. (Wilson, 1969, second peak). Perhaps a seasonal sub-humid climate with savanna type vegetation. This period may represent many short periods of climatic fluctuation (suggested by Butzer/

Butzer, 1965). This period is characterized by seasonal but fluctuating rates of discharge with high sediment yields and transportation may reach the limits of the piedmont zones. Pediment development during this period may be considered as optimal and the remodelling of the pediment surfaces may have taken place several times.

C. During a subsequent period deposition may have prevailed with the formation of fan and glacis. This period is characterized by seasonal semi-arid climates with mean annual precipitation of perhaps 300 mm. (Langbein and Schumm, 1958, peak). Perhaps a desert-steppe type of vegetation, irregular discharge but relatively high sediment yield. Transportation appears to be within the pediment zone and deposition seems to prevail during this period. Mensching (1973) related the fan formation to the Quaternary. According to Mensching (1973), the glacis formation does not go back as far as the Tertiary period, but on the contrary he stated that "the terracing, which nearly always is to be found, is mainly of the Quaternary age" (p. 134).

D. The present system indicates reduced fan accumulation, occasional discharge, and reduced sediment yield. This period is characterized by the presence of sand dunes and sand sheets near or over the surface of fans and the pediment alluvium cover. It is also characterized by the reduced deposition and transportation rates as well as the aeolian re-working.

The definition of alluvial fans has wider agreement among geomorphologists than have definitions of pediments. They are depositional surfaces forming a cone radiating from the source area (apex) downslope to the local base level. From aerial photographs, bahadas and pediments (especially those covered with glacis) sometimes look the same. It has been found that there is/

is no distinct size, shape, or tone difference between some bahadas which are surfaces of deposition and aggraded pediments which are essentially erosional surfaces developed in bedrock. There are of course some cases when the radii of the fans are shown clearly, otherwise the distinction can only be made in the field by investigating the basin filling, the processes, and the type and the depth of deposition. Such investigations should also include examination of stream cuts, surface outcrops, and the stratigraphy of these features before the decision can be made as to whether particular features are pediments, glacis, or bahadas. The transition between basins and mountain ranges may occur with a sharp break of slope forming pediment with or without a gradually sloping veneer of detritus.

If we consider the situation (during 'cyclic time span', and with geological stability) that each mountain range has some local base level in the adjacent basin, below which it cannot be eroded, then, if the reduction of the mountain mass involves slope retreat, this implies the extension of pediments. Depending on the rate of supply or removal of sediments to or from these pediments, the bedrock surfaces could either be mantled by or freed from alluvium. The observation of the accumulations in the field lead to the speculation that they may be result of a change in the climatic variable. This point was discussed earlier but one can pursue this further, to say that the relicts of the pediments in both locations (A and B) of the study area are indications of a geomorphological vestige of a semi-arid climate if other variables (such as geology) are constant.

It has been found that the surface of an alluvial fan slopes more or less gently from the highlands. Near the apex, however, the slopes may approximate/

approximate the angles of repose for the material. But with increasing distance from the source area, the slopes range from less than 1° to not more than 8°. The deposits are composed of coarse and poorly sorted sediments exceeding 8 metres in thickness in many places. The deposits below one metre from the surface do not include large quantity of pebbles as in the case of the glacis developed over the pediments (see fig. 74). In general, deposits are more stratified than in the case of the alluvial cover over the pediments. Still, the fan deposits, compared with river or lake deposits, are rudely stratified or without stratification. The silt fraction is more in fan deposits than in pediment sediments, and the fine material contains much more silt fraction than clay (see tables 33 - 82 and 108 - 137). Particle size distribution covers a wider range than in the case of pediment sediments and the actual distribution tends to be leptokurtic. Quartz grains finer than -2 phi are, however, in the range of 2 - 4 phi with some species of clay minerals in the range of 8 - 10 phi. The gradual decrease in the particle size (from gravel to silt) and the difference between the upper parts and the lower parts of the fans (FXI and FYII) indicates that the energy of the environment was diminishing down the fans. Sheetflow is a possible explanation, but debris flow was also observed and mapped (fig. 76).

Debris flows have been looked at in the field to confirm the mapping from aerial photographs shown in figure 76. Debris flows have also been reported from other areas by several authors (e.g., Bull, 1964a, Hooke, 1967). Field inspection shows that these kinds of deposits are bouldery materials containing little clay. They contain elongated fragments strongly aligned approximately/

approximately parallel to the flow surfaces. The boulders and cobbles are mixed within the mud phase without evidence of erosional surfaces beneath them. This suggests that all the fragments may have been deposited at the same time. However, because these deposits lie outside the sample area detailed analyses have not been undertaken. This indicates the need for future work to be carried out in order to bring in more information about fans and their deposits.

The data collected on alluvial fans cannot be sufficiently representative to establish useful information about climatic changes. However, the evidence obtained indicates that there might have been several climatic phases. The problem is that the number and the duration of these climatic oscillations is still a matter of speculation (see Mensching 1970, 1973, and Busche 1972). However, this point has been discussed earlier (see p. I-171 - 176).

Assuming that the variables such as geology and the initial relief are independent and that Schumm and Lichty's (1965) time scale is the 'cyclic time span', then the following suggestion may indicate the stages of development as revealed by field investigation, sediment analysis, and other field evidence from Saudi Arabia and similar parts of the world:

1 - past system: (Tertiary?) pediplanation with equilibrium between sediment yield and transportation (high discharge resulted from long periods of torrential rainfall, see Mensching, 1973).

2 - unknown periods: between 2 and 3 may have been many periods of climatic fluctuation (suggested by Butzer, 1965).

3/

3 - past system: (Quaternary) (perhaps late Quaternary): glacis formation on pediments, accumulation of fan deposits, and accumulation of gravel plains.

4 - present system: slight erosion of pediments and channeling of fans (low discharge and more wind erosion and sorting).

Further investigations are required to test the above speculations. The basic need lies in collecting sufficient evidence from the past as well as the present. Such information as archaeological evidence, carbon dating, and stratigraphic relations are indispensable to the study of the intensity of the processes, duration of climatic fluctuations, and the distribution of the processes in time and space. In connection with this a greater understanding of the contemporary denudation system can only come from more investigations concerning the probable occurrence of sub-surface runoff, the incidence, and the amount of absorption in alluvial deposits. Such investigations would provide more information about present day climate and hydrology in the area. Hydrology is another factor that can provide initial assessment for water resources in areas where their major problem at present is finding water.

According to Cunningham and Griba's (1973) slope model, "if the landscape is of a uniform lithology which does not form free-faces, the model proposes that the angle of all slopes are being reduced, but that the rate at which this reduction occurs varies with the suggested hierarchy of process. If, however, the landscape is in a series of formations which differ in lithological character, then, according to the model, each formation will exhibit an individual slope profile at any stage in recession", (p. 58). The possibility of parallel retreat of the entire hillslope is refuted/

refuted by their model. If a mountain range has some local base level in an adjacent basin, it cannot be eroded to an elevation below this level. Through time, the reduction of the mountain range would inevitably result in slope retreat which may include the development of pediments and/or fans. The suggestion that pediments and fans result from the reduction of the adjacent mountain ranges through time is difficult to refute. Lustig (1969) argued that this hypothesis on the origin of pediments is logical but lacks quantitative support. However, he argued further that, if the assumption that pediments are the results of mountain reduction is correct, then, "the average mountain mass should be significantly smaller in certain areas that are characterized by the existance of pediments", (Lustig, 1969, p. D67). His trend surface results show that, 'on the average', the areas characterized by pediments are occupied by significantly smaller mountain range areas (which also have longer erosional history) than the areas characterized by fans. He pointed out that although for some part the total variance of topographic parameters (length, width, height, relief, area, and volume of ranges) arises from local 'components', ".... there is a significant regional variation in topography, and this coincides with the regional variation in the distribution of fans and pediments", (Lustig, 1969, p. D68).

Denny (1967) showed that a given area of uplands can only produce enough coarse debris to cover a proportional area of desert plains. If this is correct, then it is interesting to investigate the relationship between pediments and fans and their drainage areas. The answer to this problem lies in future investigations on regional drainage characteristics and the distinction between fan and pediment areas in the study area as well as in other parts of Saudi Arabia.

Other/

Other problems that need further investigation

Large quantities of debris (in the alluvial accumulation, such as fans and gravel plains deposited by streams of periodic flow, along their short courses) act as excellent aquifers. Investigation of such features is needed for further progress in the search for underground water. Gravel plains and other permeable beds are important fields for analytical studies in connection with water problems. Detailed geomorphological studies of the present drainage system together with climatic data could usefully be applied to those problems and any future work should include such studies in the programme. The application of such studies would contribute greatly to the work of hydrologists concerned with the estimation of water resources. Further, the analysis of the precise factors governing the stream behaviour is of practical application not only to hydrologists, but also to geomorphologists in their attempt to explain the landforms for other practical purposes. The inter-relationship between the volume/velocity of a stream and its drainage area and channel characteristics are not only essential to our understanding of the stream behaviour hydrologically, but also of fundamental significance in geomorphology.

Wadis, in many parts of the study area, assume a branching pattern, manifest entrenched meanders, and reveal a number of river terraces which all are indications of former river action of a type very different from that of the occasional floods of the present day climate. It is becoming increasingly evident that investigation into alluvial fan deposits is needed in any future work to reveal detailed information about large and small scale climatic fluctuations and their effects on the landforms. This requires/

requires recognition of changes of processes through time that are accompanied by consequent changes in fan and other form morphology. The most likely cause of changes in landform morphology is the climatic fluctuation that occurs throughout the area. In addition, other factors which have some effect on the relief modelling should also be included. These factors are: lithology, mean slope, vegetation cover of the drainage basin, the analysis of the drainage basin itself, the tectonic movement, the geomorphology of the adjacent features, the depositional or erosional surfaces.

The major problems outlined above and indeed, many more, require to be investigated before our understanding of the geomorphology of the study area as related both to Saudi Arabia and to other desert landscapes can be widened and deepened.

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APPENDICES

APPENDIX A : THE DEVELOPMENT OF GEOMORPHOLOGICAL MAPS

APPENDIX A

The Development of Geomorphological Maps

Mapping the landform is one of today's fundamental tasks in Geomorphology and the geomorphologists's job for the recent needs is to provide as many detailed geomorphological maps as possible. This is because the content of such maps is of great importance not only to geomorphology, but also to other sciences such as Pedology, Geology, Hydrology, Plant ecology, etc. In fact the aspects of the detailed geomorphological map are very important for the preparation of agricultural schemes and for conservation programmes.

Undoubtedly, the argument can be kept within the field of geomorphology where it could be stated safely that the widespread use of the geomorphological maps has led to more detailed geomorphological enquiries with the result of a further development and progress of Geomorphology as a science. It could be argued that the advance in geomorphology is made by obtaining more information about the earth's crust, its development, and the rules which govern such development. Thus it should be easier to facilitate more accurate control over, or even better understanding of, the environment used or made by man. If this holds true, then the foregoing statement will not only stand true in the case of geomorphology but could be modified to include some parts of the Applied physical and human Sciences. Although the study of landforms and the methods applied in such study involve some difficulties, they are, together with the geomorphological mapping, leading to a better appreciation and thus to a more efficient application of regional geo-sciences.

The demand for geomorphological maps comes from the fact that most geomorphological/

geomorphological results are important for geological, ecological, hydrological and agronomical investigations. It is because the landform often provides important clues in delineating hydrological, geological and ecological boundaries on reconnaissance mapping exercises. One of the main reasons for giving priority at present to geomorphological mapping is the stress of the economic demands because such maps are not only scientific documents in their own right, but they have also proved to have been very valuable references in the assessment of resources. Since the existing relations between the geomorphological characteristics of a given land and the other factors of its environment cannot be ignored, therefore the existence of the geomorphological maps is not likely to be neglected.

Although photo-mosaics could be used directly as a field guide or in the office for preliminary surveying, they are not of great value for immediate practical application. Although they represent every detail of the terrain photographic image, they have certain problems that affect their readability and need interpretation. Such a problem is the density of the objects recorded on films which in turn depends on the sensitivity of the film used. The sensitivity of the film used largely corresponds with the sensitivity of the human eye. Thus, film types having different sensitivity would produce a different pattern density.

It has been widely accepted that stereoscopic viewing (three dimensional) is a better aid for object identification than the two dimensional viewing of the photo-mosaics. Sincs geomorphology plays a major role in any integrated survey, for practical purposes, a geomorphological map would have the advantage over photo-mosaics, in a way, that these photographic recordings have already been geomorphologically interpreted.

A/

A geomorphological map is a quantitative and qualitative record of the landforms in terms of their position in time and space. It also represents the forms as components of a geomorphological system. In addition, it carries the necessary lithological and sedimentological data. In fact a geomorphological map differs from other types in that it prevails the landform groups and the relief types on morphologic, morphometric, and/or morphogenetic bases. Thus it can contribute considerably to the scientific and practical purposes.

The geomorphological maps which have been constructed or are under construction in most parts of the world are only the result of the recent functional approach towards applied geomorphology. Until the forties of the twentieth centry, constructing geomorphological maps has not been fully appreciated. Even though Passarge had published his map in 1914, the worldwide attention was paid to the literary description of the landforms while Passarge's map was the only one of its kind. Few morphological maps were published during the thirties and forties of this century, most of them were merely individual work and they were mainly drawn to serve the purpose of presentation. Much more geomorphological work during the 1940's and early 1950's were accompanied by some diagrams and maps but these maps were of very little use for the development and planning purposes because they only were meant to illustrate the author's results. Linton (1951), however, developed a comprehensive scheme for recognition and mapping the landforms by using special/

special symbols (see Savigear, 1965, p. 514). Savigear (1952) and Waters (1958) have developed further this scheme so that Savigear's first map (1965) is a comprehensive representation of slope mapping.

The International Geographical Union System

The first international agreement on the importance of the detailed geomorphological maps among geomorphologists was made during the 1960 meeting of the International Geographical Union (I.G.U.) in Stockholm. The meeting of the Commission on Applied Geomorphology of the I.G.U. ended by setting up a sub-commission on morphological mapping to provide detailed information towards a possible unified system for such mapping.

The first meeting of the I.G.U. sub-commission was held in Poland two years after Stockholm I.G.U. meeting. The results of the discussion were very valuable in dealing with the problems of geomorphological mapping and very promising as a changing attitude towards the issue of the unification of the legends of the geomorphological maps. Since then more contributions have been added and more results been published (see Klimaszewski 1963, Demek 1967, Ganeshin, 1967, and Bashenina, et. al., 1968).

Mapping geomorphological features in detail has been the interest of Poland, Russia and France since 1950. But each country was independantly constructing its own mapping system and its own legend. When these maps were finally published the result was more confusion about the unified content of a geomorphological map. Not until the meeting of the I.G.U. sub-commission in Poland was the foundation of the unified key considered and what content or legend of such maps should be acceptable to represent the geomorphological problems in these maps (see Bakker, 1963).

The/

The legends of the maps presented during the I.G.U. sub-commission meetings in Poland, Strasbourg, Paris, London and Bϕrno-Bratislava (from 1962 to 1965) have had certain unification. Most of these maps represented the landforms by linear boundaries and by relative elevations as well as some morphometric data such as slopes. Although this was the general impression, some maps differ quite strongly in the mapped forms, the form type, and the form group. The Polish, the Hungarian and the French maps for instance show the slope in different ways. The river bank forms have also been shown quite independantly in those maps. This is also notable in the presentation of the shore forms in the French and the Russian maps.

These problems and many others such as symbols, colour and scale were discussed and modified since 1965 and the final results were produced by a special committee as an approved legend and unified key to the detailed geomorphological map of the world which they claim that the project with less differences in the maps content should satisfy the criteria of all regional characteristics and therefore should meet the different requirements (see Folia Geographica 1968).

The detailed geomorphological map of Poland

The first and the best detailed geomorphological maps published were the Polish maps in 1952. Although these maps were the most advanced of their types at the scale one to fifty thousand, the legend could not meet all the required information to be represented in a single map.

The Polish geomorphological survey was based on plotting the investigated landforms/

landforms on a topographical map using symbols to state the landforms on the morphometric, morphogenetic, morphographic and morphochronologic basis. It has been designed to represent the age, agent and process relationships.

In order to show all the complications of the investigated data on a map, the Poles have added colours besides symbols. The colours were originated to indicate both the age and the origin of the landforms (see Klimaszewski 1956, 1960, 1961, 1963, and Galon 1962, 1963).

The French Carte Geomorphologique detaillée

France started its own geomorphological maps in 1953. The aim of the morphological mapping was to give a complete and detailed information about the geomorphological evolution of the region planned to be mapped; its history, lithology, structure, the nature of processes and the type of the landforms. It has been designed to provide sufficient data for both practical and fundamental purposes. The French produced maps for some parts of Africa (Senegal and Niger), South America (Venezuela) and France. Their methods differ from the Polish one in giving priority to the lithology, processes and age of the landforms. It has satisfied the demands of the rural improvement, soil conservation and irrigation by listing most of the geomorphological elements which have influenced the soil formation. In Venezuela they used the geomorphological map as a basis for the pedological mapping in order to provide data for the biogeographical studies and for the conservation programmes. In this particular instance the use of aerial photographs has played an important part because of the absence of the basic maps and the lack of sufficient background. The information given in the map of the Venezuelan Andes/

Andes shows mainly the inter-relationship between the tectonic Paleoclimatic variation and the Quaternary as well as the present geomorphological changes under various climatic conditions (see Joly 1962, 1963a, 1963b, 1967, Tricart 1954, 1956, 1963a, 1963b, 1965, 1969, Tricart and Michel, 1965, and Tricart and Vogt, 1967).

The morphological maps of the Soviet Union

The Russians have been developing their small scale maps since 1950. The first were published on the scales one to four million and one to five milli but when it was modified to match the I.G.U. standard it was published on the scale of one to one million. The small scale maps were designed to overcome two major problems: the type of the morphological features to be mapped, and the colour to be used to represent the landforms. Although these maps were to represent the morphographic, morphogenetic, and morphochronologic characteristics the stress was laid upon the morphogenetic principles.

The large scale maps (1:50,000 - 1:25,000) are most elaborate in comparison with the smaller scales. They were designed to cover two major groups of landforms: families of landforms and single landforms. They also distinguished between river valleys and the development of their terraces as well as the relationships of different elements and forms using base colour to show the genetic characteristics, shading and hatching to represent the forms in a chronological order, and a mixture of contour lines and symbols to show the morphological data. Although these kinds of maps are well balanced, the complexity of their content makes them very difficult to read. Apart from the approximation of the contour lines in relation to slope values, these maps have nothing to show the morphometric values of the slopes. They also neglect/

neglect the descriptive factors of the landforms in order to concentrate on the origin and the age (see Borisevich 1950, Ganeshive 1967, Svaricheskaya 1967, and Bashenina and Zaroutskaya 1967).

Many other countries have contributed to the I.G.U. system among those are: Czechoslovakia (Demek 1963, 1967), Hungary (Pecsi 1963 and 1964), Belgium (Pissart and Macar 1963), East Germany (Gellert 1963, 1967), Canada (St. Onge 1964 and 1968), Japan (T. Nakano 1961), and Great Britain (Savigear 1952, 1956, 1959 and 1965).

The principles and methods of the I.G.U. Sub-Commission System

The discussions of the sub-commission have revealed the agreement that the detailed geomorphological maps should contain information about the shape, the size, the origin, and the age of each landform to be mapped. The signs and symbols should be very clear and simple in order to describe the landforms more precisely.

As far as the age of landforms is concerned it should be shown by shades of colours within each genetic group and if possible the International Geological Abbreviation. Since the slopes are the most difficult elements of the landforms to be represented in a plane, the I.G.U. system has not been able to produce satisfactory categories for slopes and therefore it has been agreed that it would be represented in the shades of grey to cover six slope values ($0 - 2^{\circ}$, $3 - 5^{\circ}$, $16 - 35^{\circ}$, $36 - 55^{\circ}$ and over 55°).

Although the I.G.U. sub-commission legend covers a large variety of landforms to be mapped in terms of its process and the regional development, it neglects a good deal of non European regions. The deficiency in the amount/

amount of information available in many non European maps is due to the fact that very little geomorphological surveying has been carried out in those regions. This also applied to those regions where accurate data, topographical and/or geological, and aerial photograph coverages do not exist at all. The detailed geomorphological mapping scheme, designed by the I.G.U., depends on the existence of at least medium scale topographical and geological maps. However, in many parts of the world it cannot be achieved directly because of the lack of such basic information and the problem of the time necessary to carry out such programmes from scratch. Therefore, the mapping scheme for the study area has been compiled on the basis of aerial photographic interpretation with the aid of field investigation where possible.

<u>The I.G.U. commission of geomorphological survey and mapping</u>

The sub-commission of the I.G.U. has enlarged to the commission of geomorphological survey and mapping and their first task was to define the geomorphological map. It has been defined as maps representing the relief of the continents and the bottom of the oceans as the boundary between the solid body of the earth and its fluid and gaseous envelopes. Geomorphological maps are finally divided into the following types according to their purposes and use:

1. General and partial geomorphological maps designed for pure geomorphological research.
2. General and partial geomorphological maps showing certain relief properties and features for various practical applications.
3. Geomorphological maps for the use of other scientific demands such as tectonics,/

tectonics, hydrology, geology and geophysics.

The scale range varies from one to ten thousand to one to thirty million according to the purpose of presentation. The aims and the legend are what was discussed and suggested by the sub-commission on geomorphological mapping. In fact the commission has carried out what has been said by the former sub-commission which is the experience of several European countries in geomorphological mapping. Thus the incomplete picture of the problem of mapping for the whole world remains the major issue for the future.

The International Institute for Aerial Survey and Earth Sciences (I.T.C.) geomorphological mapping system

Dealing with aerial photographic interpretation, aerial survey, photogrammetry, and the earth sciences, the I.T.C. have realized the great advantages of the application of the aerial photographic interpretation and photogrammetry in compiling a geomorphological map. The use of aerial photographs in geomorphological mapping is particularly important for many parts of the world where there are more urgent demands for planning in a short period project or where the basic information is not easily obtainable.

The I.T.C. system included the four fundamental aspects of the landforms; morphometry, morphography, morphogenesis and morphochronology with reference to lithology and processes. Although this system includes some standard surveying methods and although its legend is a mixture of other legends, the photographic interpretation remains the most important procedure for geomorphological mapping.

By using photo-mosaics and/or some rapid scanning of photographic coverage,/

coverage, a topographic base map could be made. Subsequently a preliminary morphological map of the landform features can be plotted. Field and laboratory investigation comes next which will eventually lead to the completion of the final detailed morphological map with the aid of aerial photographic interpretation.

The system has been devised to produce three types of maps: preliminary maps, general purpose maps and special purpose maps. The preliminary maps are based on photographic interpretation to serve the purpose of constructing either or both general and special purposes maps. The two other maps are based upon more extensive field investigation, field surveying, field checking and laboratory results.

The stress here is laid upon the major genetic landform units. It has been also designed to accommodate a wide range of scales as well as the smallest possible range of colours. It also distinguishes eight forms of origin: structural, volcanic, denudational, fluvial, marine, glacial, eolian and karst landforms. These forms are shown by what has been called 'coloured area symbols' while the lithologic, morphometric, topographic and chronologic interpretation are shown by black and/or grey shades and/or symbols.

The amount of detail obtainable for mapping by this method varies from one area to another depending on the type of terrain, the quality of photographs, the scale of photographs and the available maps, the availability of information and access to the field work, and the intensity of the vegetation cover. The overall application on the other hand, considering the problems of photographic interpretation such as distortion of the photographic image, should ensure an accurate detail and quick representation of the landforms specially/

specially when the topographic maps are not available.

Finally, compiling maps according to the I.T.C. system without full field investigation will produce the present features of the landforms in its static state neglecting the active geomorphological processes and their effects. But the progress in the aerial photographic interpretation techniques and the use of more advanced instruments have added a great reliability and accuracy in geomorphological mapping from aerial photographs with minimum field investigation (see Verstappen 1959, 1963, and Verstappen and Zuidan 1968).

The I.G.U. system and the I.T.C. system for geomorphological mapping could be compared as follows:

1. The I.G.U. system is a procedure for geomorphological mapping based on intensive field and laboratory investigation and field surveying. While the I.T.C. system depends mainly on the interpretation of the aerial photographs with the aid of field investigation and photogrammetric reconnaissance.
2. The classification of the landforms and the mapable units are more detailed in the I.G.U. system.
3. The construction and the completion are based on detailed topographic maps in the I.G.U. system. But with the I.T.C. system the mapping could be done by using controlled photo-mosaic if there are no such maps available.
4. The scale in both systems has to be large enough to include more detailed information.

5. Both systems include symbols and colour shadings to the content of the maps.

6. The difference between the symbols and the colour shadings of either system is not great but the number of symbols and colour shadings is very large in the I.G.U. system.

7. Both systems have different purpose maps with different scales. The content of the general purpose maps, however, in the I.T.C. system is more generalized than the I.G.U. system general purpose maps.

8. Some of the symbols and shadings of both systems cannot be compiled without cartographic difficulties.

9. Both systems include the morphometrical, morphographical, morphogenesis, and morphochronological aspects of the landforms.

APPENDICES

APPENDIX B : THE THEORY OF SIEVING AND SEDIMENTATION

APPENDIX B

The Theory of Sieving and Sedimentation

The concept of particle size

Since most particles of the sedimentary rock - aggregate or solid - are of irregular shapes, the concept and definition of size will be very difficult to establish and it is, therefore, a matter of approximation and comparison with the particle shape. The problem of size determination arises from the fact that each particle has to be measured separately if the actual 'physical' size is to be found. But since this is very difficult to achieve in practice, it becomes necessary to choose an arbitrary approximation of the particle shape from which the size can be estimated.

The size of a particle, if defined as a linear dimension, is a function of the particle volume or form and is, therefore, arbitrary. When the size is to be determined, say by sieving, the actual size of the particles has to be ignored because the size here is only a functional property of the particle form determined by the way in which different particle shapes pass through a fixed shape of the screen openings.

The definition as mentioned above is also applied when the particle size is to be determined by sedimentation techniques. Udden (1914) supported/

supported this argument by showing the relationship between particle-size modes and different kinds of particle movement.

Wadell (1932) argued that the size of a particle is best expressed in terms of its simple volume value because the volume is, according to him, independent from the particle shape.

Particle-size, however, in its broad definition, as determined by mechanical methods, is merely an estimation of the diameter of a sphere of equal volume to that particle.

The transformation of particle sizes into some linear dimension has been, generally, expressed in terms of millimetre units. Wentworth (1922), adapted this scale to be used for size analysis in the field of Sedimentary Petrology and it has been known since as the Wentworth scale. To make the scale more easily calculated when more statistical analysis are needed, Krumbien (1934), introduced his Phi unit which is the logarithmic transformation of Wentworth scale. The Phi unit could be obtained from Krumbien's (1934) formula:

$$\Phi = -\log_2 d \quad \text{or} \quad d = (\tfrac{1}{2}). \qquad (1)$$

Where d is the particle size in Wentworth scale, and Φ is the Greek letter Phi which denotes the logarithmic transformation of the Wentworth scale.

Although particle size analysis by mechanical methods has been considered as an important tool in the field of Sedimentology, and the majority of investigators in other fields seem to be fond of such methods, great care must be taken before any attempt is to be made to interpret/

interpret the data revealed by these methods.

It is for this reason, as well as for the justification of the conclusions derived from the data obtained by mechanical methods and the development of theories discussed later, that this introduction on the principles of size analysis has to be written.

Gravel analysis

Gravel analysis has been designed to obtain information about the provenance, length of transport, and possible climate during transport from the depositional fabric, size, form, rounding, and petrographic composition of pebbles.

Cailleux (1947, 1952) measured three variables to calculate the flatness ratio of pebbles which are: L, I and E and two variables for measuring the roundness of pebbles which are: R and L.

The equations for calculating the flatness ratio and the roundness of pebbles are:

$$\text{flatness ratio} = Fr = \frac{L + I}{2E} \qquad \text{(Cailleux)}, \qquad (2)$$

Where L is the longest diameter of the pebble, I is the greatest width, and E is the greatest thickness,

$$\text{roundness} = R = \frac{2R}{L} \qquad \text{(Cailleux)}, \qquad (3)$$

Where R is the smallest radius of curvature of the least rounded part of the pebble, and L is the longest diameter.

Sieving theory

Sieving,/

Sieving, undoubtedly, is one of the most popular and earliest techniques used in particle size determination of clastic sediment. This method has been successfully applied to determine the particle sizes in the range between 4.0 mm. and 0.062 mm.

Although the technique is very simple to apply, the theory of sieving seems to be not as simple as the practical side of it. Problems such as experimental errors, deficiency in screen openings are perhaps more difficult to overcome than the actual practice of the technique. Care of such errors in every step of the experiment should be emphasized specially in the final analysis.

Sieving has been defined as the process by which a number of small spheres of a given mixture pass through a sieve during a particular time. This definition was expressed mathematically by Krumbein (1938 in: Krumbein & Petijohn 1938), as follows:

Since $$dy / dt = -ay; \qquad (4)$$

which by integration will yield;

$$\log y = at + \log c; \qquad (5)$$

which by evaluation of log c at time t = 0 becomes;

$$\log c = \log y; \qquad (6)$$

then c is equal yo which is the original number of small spheres in the mixture. Substituting yo for c and rearranging equation (5) will yield;

$$y = yo \; -e^{-at}. \qquad (7)$$

where y is the number of small spheres in the mixture at time t, and

a/

a is the constant of proportionality.

Most of the sieving theories such as equation (7) by Krumbein (1934), are based on the assumption that the amount of a given mixture of particles falling through a sieve is proportional to the amount of material retained on the sieve at that moment.

Sahu (1965a and 1965b), has given a quantitative estimation of the measured dependency of particle size upon the shape and roundness of these particles in various possible cases. The results of his arguments on the grain shape and roundness and its relation to the size are very helpful in the interpretations of the data obtained by the sieving method. In his second work on the theory of sieving Sahu (1965b), emphasizes that the shape and roundness of the particle affect the size which he described as 'the intermediate diameter' of a symmetrical tabular grain which in turn controls the sieving characteristics of such particles.

The probabilistic approach of the particle passage through a sieving screen which was introduced by Gaudin (1939), has been of interest to many workers, including Fagerhalt (1945, in Dallavalle, 1948), Whitby (1959), and Mirva (1960 in: Orr 1966). In more recent work Ludwick and Henderson (1968), have discussed the analytical and probabilistic theory of the multi-screen sieving of variously shaped, three dimensional particles through real screens. Their result is a method of computing tables giving the probability that an ellipsoid of/

of grain size and shape will be present at a particular sieved fraction after a stated length of sieving time.

The method of particle size analysis by sieving has neither been considered a precise method nor has it been accepted as an accurate tool for measurement if there is no assumption made about the particle shape and if no calibration method for the screen openings used. Ludwick and Henderson (1968), gave 10 - 20% underestimation of the modal intermediate diameter of particles in each sieved fraction.

Inaccuracy of sieves and sieving has been mentioned by a number of investigators and the deficiency of sieving and its effect on particle size analysis has the attention of several authors such as Hatch (1933), Krumbein (1938 in: Krumbein and Pettijohn 1938), Bagnold (1942), Keller (1945), Inmann & Chamberlain (1955), Mason & Folk (1958), Friedman (1961), Folk (1962 & 1966), and Griffiths (1958, 1959, 1962 & 1967).

The defect is that most of the intermediate diameters of the particles in a sieved fraction lie outside the nominal openings of the limiting screens. Whitby (1954 & 1959), gave a comprehensive discussion on the mathematical physical laws that govern the sieving of small particles. He showed that sieving under non-steady-state conditions is divided into two different regions connected by a transition region. During the early stage of sieving, the quantity of sediment passing per second/

second is constant, while during the later stage, the quantity passing per second is said to decrease with time according to a log normal rate of fall-off. But still he has not classified his method of handling the particle shape. He also stated that the screen variation was not considered significant.

The probability of small grains lying over an open sieve hole depends on the size of the sample, the grain size distribution, and the number of screen openings per unit area. Batel (1960) stated that the probability of a grain passing through the sieve increases until the sieve surface is completely covered with sieving material.

The nature of the separation of grain size by sieving can be defined clearly, according to Schneiderhon (1953 in: Muller 1967), in two directions. The first is that the diameter allowing passage through the sieves rests on the assumption that the intermediate, 'the mean', diameter is the only side in which it is more likely to pass through and, therefore, the grain size can only be defined in terms of a single dimension. The second is that the probability of grains with three unequal axes passing through a given sieve is very low because these grains can only pass through in one position. This definition by Schneiderhon (1953) is valid in the case of grains characterized by one major axis (c), and two minor axes of equal length (b + c).

The factors involved in the accuracy of sieving or in the

deficiency/

deficiency of the sieves can be summarized as follows: a) the particle shape or form; b) the particle surface texture; c) hygroscopicity coefficient;[1] and d) the development of electrostatic charges. The other factors that care should be taken account of are the sieving procedure, the sample size, in relation to the size and the number of sieves, the duration of sieving, and the type of sieving (e.g. dry or wet sieving).

Nevertheless, sieving as a method of particle size analysis can produce significant results when it is used to determine the sand and gravel size for general purposes, provided that care has been taken. It has already been accepted that for detailed analysis of particle forms and their influence on the composition of sediments, sieving could only be considered as a preliminary stage to separate particle grains into more specific classes for further analysis by different methods such as microscopic and/or pipette analysis.

It has also been proved that sieving produces more accurate results when the mesh openings, the grain density, and the grain movements are reduced. It can also provide good results when the sample weight, surface texture, preparation of coarse grains and the deviation from spherical form increases.

Screen/

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1. Hygroscopicity is the factor which measures the tendency of sieves to absorb moisture.

Screen calibration

Although the use of the calibration method may lead to erroneous results, it has been found to be the most common technique used to overcome some of the sieving problems.

Screen calibration is necessary when one is looking into the complex differences between environments. Folk (1966), found that the screens might have been as much as 0.15 percent off their stated diameters. Such a difference will not be of importance if the measure of the central tendency is desired, but they can produce effects on fine parameters such as skewness and kurtosis.

Calibration could be done, according to Folk (1966), by sieving several sands from different areas, say beaches which in most cases approach the normal distribution. If each sand has a "kik" at the same phi unit ("Φ") reading, then the screen must be suspect and the screen opening should be measured under a binocular microscope. Bagnold (1942), after measuring the screen openings, found that an adjustment consists of a device such as piloting the sample on a graph paper then by tracing the "kik" points and alter where necessary is more accurate than the microscopic examination by itself.

Finally, it should be indicated here that sieving will yield some information that can be used to compare different samples. It can also reveal useful information which will, surely, assist in the attempt to describe the sediments. But care should be stressed here because any attempt to interpret the physical property of a sample in terms of size/

size and form on the basis of sieving will be considered with great caution.

Settling velocity

Another technique used in the mechanical analysis of particle size is sedimentation analysis by settling velocity. The calculation of the settling velocity of a particle in a fluid or gas will largely depend on the particle diameter, form, density, and the surface texture as well as on the fluid density, viscosity, and temperature. The acceleration due to gravity is another factor which has to be taken account of.

A very small particle will settle in a fluid (e.g. water or alcohol), with a constant velocity. The particle will reach this state as soon as the resistance of the fluid and the force of gravity which act on the particle, are exactly equal.

Most techniques used to determine the particle size by means of settling velocity, or sedimentation as it may be called, will depend on the laws introduced by Stokes (1845), and/or developed by Rubey (1930), Wadell (1933) and Krumbein (1934).

Stokes' law is based on the assumption that the fractional resistance of a quiet sedimentation fluid - or gas - upon a sinking spherical particle can be expressed as follows:

$$V = \frac{2}{9}\frac{(d_1 - d_2)\, gr^2}{n}, \qquad \text{Stokes} \qquad (8)$$

where/

where V is the particle velocity in cm/s^{-1}, g is the acceleration due to gravity equal to 981 cm/s^{-2}, d_2 is the density of the fluid or gas in g/cm^{-3}, d_1 is the density of the falling sphere in g/cm^{-3}, n is the viscosity of liquid in g/cm^{-1} / S^{-1}, and r is the radius of sphere in cm.

For values greater than those stated by Stoke, Rubey (1930) introduced his formula:

$$V = \frac{4}{3} gd_2 (d_1 - d_2) r^3 + 9n^2 + 3n^{\frac{1}{2}} / d_2 r, \qquad \text{Rubey} \qquad (9)$$

which agrees with the observed values as Krumbein (1938 in: Krumbein & Pettijohn 1938), stated.

Wadell (1933 & 1935), examined the functional relationship between the coefficient of resistance and Reynolds number and obtained the expression:

$$Vp = \frac{1}{7}\frac{(d_1 - d_2)\, grp^2}{n}, \qquad \text{Wadell} \qquad (10)$$

Where Vp is the particle settling velocity, and rp is the particle sedimentation radius.

Wadell's formula (10) as well as Stoke's law are the empirical laws in the mechanical analysis of sediment particle size by settling velocity in the field of Sedimentology.

Krumbein (1938 in: Krumbein & Pettijohn 1938), Griffiths (1967), Muller (1967), and Galehouse (1971 in: Carver 1971), have calculated tables based on Stoke's law and other laws above the range of Stoke's law for the settling velocity of particles at different temperature and various specific gravities.

It/

It must be noted here that Stoke's law is not, always, an easy approach because it can only be applied under the following conditions:

1 - All particles must have reached the terminal fall velocity.

2 - All particles must be rigid.

3 - All particles must be smooth.

4 - There will be no slippage or shear which could take place between the particle and the fluid.

5 - The fluid must be of infinite extent in relation to the particle.

6 - The concentration of the particles in the fluid must not be more than 1%.

7 - The particles must be larger than 0.5 u in diameter.

8 - The particles must not be larger than 50 u in diameter.

9 - All particles must be spherical in shape.

Most of the above mentioned conditions imposed when applying Stoke's law can be fulfilled in sedimentation analysis. But the difficulty arises when conditions 3 and 9 are to be fulfilled. It is more obvious that the natural grain has a rough surface rather than a smooth one and it is far from the spherical shape. Nevertheless, the method could estimate the conditions in which the sedimentation processes have been acting to formulate such form.

Pipette Analysis

This technique of mechanical analysis of particle size is the sedimentation method by pipette analysis. The technique has been designed to calculate the settling velocity of the particle sizes in

a/

a fluid medium in terms of the quartz sphere diameter from Stoke's law and any other formulas designed to calculate the sedimentation diameters above the range of Stoke's law.

The pipette method has been used to estimate the small particle sizes (e.g. silt and/or clay), which cannot be achieved by some other methods such as sieving, where only the coarser grains can be determined. It should be made very clear here, that the actual physical size of a sediment particle is not obtainable by this technique, because only what is known as the sedimentation diameter which is the function of the three variables: the particle size, shape, and density, can be obtained by such method.

The technique is a device introduced by three independent workers in 1922, Robinson from England, Krauss from Germany, and a joint work between the three Americans; Jennings, Thomas and Gardener. Andreason, Jensen and Lundberg (1929), had developed the method and the equipment so that it has been known since as the Andreason pipette.

The method is based on the sedimentation process which produces changes in the concentration of particles, in what is originally a homogeneous suspension. Sampling can be done by sucking samples with the pipette, at certain time intervals, and immediately above the already deposited material. Each pipette sample would then be taken at such a time and depth that that particular size fraction, "sedimentation diameter", has not settled below the sampling point.

Although dispersion and disaggregation are important factors in any/

any particle size analysis by pipette, the deficiency of one of them or both will affect the results obtained by this method. It should be fully understood, however, that the size differences could be a reflection of the differences in the original composition and, therefore, will not be an indicator of the differences between the original particle sizes. This is also applied to all wet techniques which shows that from this point of view no one is a better method than the other.

Krumbein (1932), in order to show the efficiency of the pipette method, compared the results of two techniques, the pipette and the sedimentation tube. It appears from his results (table 12) that the amount of material within the sieved grades agreed very much in both methods, but in the smaller grade sizes there was a marked difference between the sedimentation tube method and the pipette.

Hellman and McKelvey (1941) made another attempt to compare the results obtained by the pipette method and what they called the hydrometer pipette. But this time the attempt was to show that the hydrometer pipette is much more efficient than the pipette. Their results are shown in tables 13 and 14. The table shows similarity in the second group and a marked difference in the finer grades of the first group.

Nevertheless, pipette analysis of fine clastic sediments reveals some accurate results compared with other methods. Even the sedimentation balance/

balance, which is the most accurate and recent technique of them all, suffers - in the same way as pipette and other wet techniques - from inaccuracy when relating the settling convection to the grain size analysis.

APPENDICES

APPENDIX C : GLOSSARY

APPENDIX C

Glossary

Aqabah : pass, rise, or slope

'Ayn or 'ain (plur. 'Uyān or 'aioon) : a natural spring, any orifice where water appears from the ground, or a feeble spring oozing generally from a talweg beside a mountain

Bajada : a series of confluent alluvial fans along the base of the mountains

Bi'r (plur. Bi'ār or Abyār) : dug well

Hamada : bare stony plateau or rocky desert whose surface is formed of angular debris. A plateau in a desert region whose rocky surface has been denuded by wind erosion.

Harrah : lava flow, area with lava flow surface. A wide expanse of lava flow, usually many square kilometres in extent, covering either level or nearly level terrain forming a rough, jagged, spinose, clinkery surface.

'Irq (plur. 'urūq) : hooked, curved or wandering dunes.

Jabal (plur. Jebāl) : a mountain or a hill.

Jilh : barren dissected tablelands or a sequence of dissected cuestas with low relief scarp faces. Usually in limestone, sandstone, or shale outcrops.

Khabrā' : a local base level mainly a basin or a depression filled with alluvial deposits.

Khashm : the front part (nose) of a hill, a mountain arm, or a mountain range. Headland or promontory, along a cliff or mountain front.

Ramlah : sand area, sand sheets, or sand dunes.

Rijm : hilly area, boulder heaps, or inselbergs.

Safrā' : a yellow plateau that is formed in limestone outcrops.

Sayh : depressions, gravel plains, or flat areas covered with thin sand sheets. Usually in sedimentary outcrops such as limestones.

Sayl (Seūal) : occasional flow of water in streams or stream channels. Occasional flood.

Wadi; wādī; wady : a ravine or water course. The term can either designate the bed or the valley. It is used for intermittent water course or permanently dry.

'GEOMORPHOLOGICAL MAPPING AND LANDFORM ANALYSIS IN CENTRAL SAUDI ARABIA'

(with special reference to the characteristics of pediments and fans)

Volume II (tables, diagrams, and plates)

By

Z.M.N. MUNSHI

A thesis submitted to the University of St. Andrews for the degree of Ph.D

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Volume II (Tables, diagrams, and plates)

List of Tables

List of figures:

List of Plates:

Table 1

Rock Units of the Shield Area

UNITS	TYPE	AGE Millions of Years
Granite	Red or pink with intrusive rocks	± 500
Diorite	Diorite and related rocks	± 530
Andesite Flows, and Intrusives	Andesite and fine-grained dioritic rocks with interbedded phyllite, quartzite, graywacke, conglomerate and marble	± 600 - 640
Amphibolite Schist	Amphibolite schist with minor beds of quartzite	± 700
Sericite and Chlorite Schist	Sericite and chlorite schist including minor lenses of quartz and marble	± 750

(See Brown and Jackson, 1960)

Table 2

THE OUTCROP LITHOLOGY AND THICKNESS IN THE SHELF AREA

Age		Formation	Lithology	Thickness in Metres	
Quaternary		Surficial Deposits	Gravel, Sand and Silt		
Jurassic	Callovian	Tuwayq Mountain	Aphanitic limestone; subordinate calcarenitic limestone and calcarenite; abundant	203	Upper Jurassic and Lower cretaceous carbonate rocks
Jurassic	Bathonian	Duruma	Aphanitic limestone and shale; subordinate calcarenite.	375	
	Toarcian	Marrat	Shale and aphanitic limestone; subordinate sandstone.	103	Lower and Middle Jurassic clastic and carbonate rocks.
			unconformity		
Triassic	Upper	Minjur	Sandstone and shale	315	
Triassic	Middle	Jilh	Sandstone, aphanitic limestone and shale; subordinate gypsum.	326	Permian and Triassic clastic rocks.
Triassic	Lower	Sudair	Red and green shale.	116	
Permian		Khuff	Limestone and shale.	171	
			unconformity		

Table 3

Rock Units of the Shelf Area

UNITS	TYPE	AGE
Eolian Sands	Quartz, Mica, and Feldspar	Newgene
UNCONFORMITY		
Silt and Gravel	Silt, Sand, and Gravel	Middle/Upper Pliostocene
Gravel	Gravel deposits of Quartz and other types from the Basement	Lower/Middle Pliostocene
UNCONFORMITY		
Tuwayq Limestone	Limestone : mainly coral-bearing	Upper Jurassic (Callovian)
UNCONFORMITY		
Duruma Limestone	Limestone and Shale	Middle Jurassic
Marrat Limestone	Limestone, Dolomite, and Red Shale	Lower Jurassic (Toarcian)
UNCONFORMITY		
Munjur Sandstone	Sandstone with vari-coloured shale	Triassic/Jurassic
Jilh Sandstone/Limestone	Sandstone, Shale and Limestone	Middle Triassic
Sudair Shale	Red Shale	Permian/Triassic
Khuff Limestone	Limestone with Shale and Marl	Upper Permian

Table 4

Summarized Lithology and Thickness of the Khuff Formation
(Ar Rayn Section)

AGE	FORMATION	LITHOLOGY	THICKNESS IN METRES
Upper Permian	KHUFF Limestone	4- Aphanitic-Calcarenitic Limestone	28.2
		3- Aphanitic Limestone with prominent bed of fine-grained Limestone	71.1
		2- Dolomite and Limestone	33.7
		1- Dolomite and Shale with subordinate fine-grained Limestone, some beds of granitic sand, and fine conglomerate	38.4

Powers and Others, 1966, p. 115.

Table 5

Summarized Lithology and Thickness of the Jilh Formation

(Jilh al'Ishār section)

AGE	FORMATION	STRATIGRAPHY AND LITHOLOGY	THICKNESS IN METRES
Middle Triassic	JILH Sandstone, Limestone and Shale Units	5- Fine to medium-grained Sandstone and green to purple Silt and Shale with several prominent layers of Limestone	66.2
		4- Massive and crossbedded fine to coarse-grained Sandstone in the upper part, and interbedded with Silt and Shale in the lower part	117
		3- Chalky, slabby weathered, Limestone interbedded with marl and sandstone	35
		2- Green Shale, in some parts gypsiferous shale, with few thin beds of Limestone	25.6
		1- Fine to medium-grained Sandstone, locally ferruginous quartz, and light to dark-green Shale	80

Powers and Others, 1966, P. D35

Steineke and Others, 1958, PP. 1249 - 1329

Table 6

Summarized Lithology and Thickness of the Marrat Formation
(Khashm adh Dhibi section)

AGE	FORMATION	STRATIGRAPHY AND LITHOLOGY	THICKNESS IN METRES
		4- The upper part of the formation: Aphanitic and calcarenitic Limestone	24.2
Lower Jurassic (Toarcian)	MARRAT Limestone Siltstone and Sandstone	3- Shale, Siltstone and Sandstone forming the middle part of the Marrat formation	41.8
		2- Aphanitic and calcarenitic Limestone and Dolomite	
		1- Poorly exposed Sandstone, Siltstone, and Shale	21.5

Power and Others, 1966, P. D121.

Table 7

Summarized Lithology and Thickness of the Duruma Formation
(Khashm adh Dhibī and eastward section)

AGE	FORMATION	STRATIGRAPHY AND LITHOLOGY	THICKNESS IN METRES
		10- Shale	64
		9- Calcarenitic and aphanitic Limestone	25
		8- Aphanitic and calcarenitic Limestone	54
		7- Aphanitic Limestone and calcarenite	32.3
Middle Jurassic	DURUMA	6- Calcarenitic Limestone, calcarenite and aphanitic Limestone	36.1
(Bajocian-Bathonian)	Limestone	5- Calcarenite and calcarenitic Limestone	42.3
		4- Aphanitic Limestone and Shale	34.5
		3- Shale	20.2
		2- Shale, aphanitic Limestone and calcarenitic Limestone	35.6
		1- Shale, Limestone and Gypsum	30

Powers and Others, 1966, P. D123 - D129.

Table 8

Table 8 showing the aerial photographs in relation to the photo-mosaics and the study area

Mosaic No.	Roll No.	Aerial photo. Nos. from	to	Location	
				45°E.	45°30'E.
A-4(425)	48	7537	7546	24°N	24°N.
	51	7999	7990	23°45'N	23°45'N.
	50	7775	7783	45°E.	45°30'E.
				45°E.	45°30'E.
A-5(395)	50	7814	7805	24°15'N	24°15'N.
	52	8153	8161	24°N	24°N.
	52	8192	8182	45°E.	45°30'E.
				45°30'E.	46°E.
B-5(394)	50	7804	7795	24°15'N.	24°15'N.
	52	8162	8173	24°N	24°N.
	52	8181	8173	45°30'E.	46°E.
				45°30'E.	46°E.
B-6(393)	91	15275	15284	24°30'N.	24°30'N.
	90	14976	14967	24°15'N.	24°15'N.
	89	14955	14966	45°30'E.	46°E.

Table 9

LANDFORM REGIONS AND SYSTEMS

The Central Plateau Province

Scale

1:500,000 — I - The Southern Region

II - The Central Region

III - The Northern Region

1:250,000 — I - The Southern Region

(I-A) Al Mar /Umm ad Dabāh / Ataylu landform system

(I-B) Muhayriqah / Jaddalah / Quday'an landform system

(I-C) Agabat Al Mishar landform system

(I-D) Khuff landform system

(II-E) Al Quway'iyah and Al Aawar landform system

(II-F) As Sirr and Qunayfidbah landform system

(II-G) Dalqān and Lughdān landform system

(II-H) Musaquah landform system

(II-I) Tabrāk landform system

(III-J) Al Ghuzayz / Al Mirakh landform system

(III-K) Qraydān landform system

Table 10

LANDFORM SYSTEM AND LANDFORM TYPES

Name	Rock	Morphology	Landform System No.	Landform type No. Complex	Landform type No. Simple	Unit landforms include
Al 'Mar/Umm ad Dabah/Aṭ Taybi	Non-lineated metamorphic and limestone	Mountains and steep slopes	I - A	ct 1		stu 1, ctu 2.
		Flat and gentle slopes			st 2	stu 3, stu 4.
Mubayriqah/ Jaddalah/Quḍay'ān	Crystalline	Mountains and steep slopes	I - B	ct 3		stu 5, ctu 6.
		Flats and gentle slopes			st 4	stu 7, stu 8.
Aqabat Al Mishār	Lineated metamorphic	Mountains and steep slopes	I - C	ct 5		stu 9, ctu 10.
		Flat and gentle slopes			st 6	stu 11, stu 12.
Khuff	Limestone and dolomite	Mountains and steep slopes	I - D	ct 7		stu 13, ctu 14.
		Flat and gentle slopes			st 8	stu 15, stu 16.
Al Quway'iyah/ Al Ḥawar	Unconsolidated coarse textured sediments	Flat and gentle slope plains	II - E		st 9a st 9b	stu 17, stu 18.
As Sirr/ Qunayfidhah	Unconsolidated Eolian sediments	Dune complexes	II - F	ct 10		ctu 19, stu 20, stu 21.
		Deflation hollows and other sand accumulation			st 11	stu 22, stu 23.
Dalqān/Lughdān	Weakly consolidated fine textured sediments	Benches and steep slopes	II - G		st 12	ctu 24, stu 25.
		Flat and gentle slopes			st 13	stu 26.
Muṣayqirah	Coarse textured sandstone and silt	Benches and steep slopes	II - H		st 14	ctu 27, stu 28.
		Flat and gentle slopes			st 15	stu 29.
Tabrak/						

Table 10 continued

Name	Rock	Morphology	Landform System No.	Landform type No. Complex	Landform type No. Simple	Unit landform includes
Tabrak	Sandstone and shale group	Plains and some dissected areas	II - I	ct 16		stu 30, stu 31, stu 32.
Al Ghnzayz/ Al Mīrākh	Limestone	Benches and steep slopes	III - J		st 17	ctu 33, stu 34.
		Flat and gentle slopes			st 18	stu 35, stu 36.
Qraydān	Limestone	Mountain and steep slopes Flat and gentle slopes	III - K	ct 19a ct 19b		ctu 37, ctu 38, stu 39.

Table 11

TYPES OF UNIT LANDFORMS

Scale 1:50,000

Landform type No.	Morphology	Types of unit landform Complex No.	Simple No.	Approx. slope limit degrees	Landform system No.	Name
ct 1	Faulted or undercut eroded hill sides and slopes in non-lineated metamorphic rocks		stu 1	50	I - A	Steep slopes
		ctu 2		15 - 50		Hill sides
st 2	Gentle sloping parts and flats in non-lineated metamorphic rocks		stu 3	$2\frac{1}{2}$ - 15		Gentle slopes
			stu 4	$2\frac{1}{2}$		Flats
ct 3	Faulted or undercut hill sides and slopes in crystalline rocks		stu 5	50	I - B	Steep slopes
		ctu 6		15 - 50		Hill sides
st 4	Gentle sloping parts and flats in crystalline rocks		stu 7	$2\frac{1}{2}$ - 15		Gentle slopes
			stu 8	$2\frac{1}{2}$		Flats
ct 5	Faulted or undercut eroded hill sides and slopes in lineated metamorphic rocks		stu 9	50	I - C	Steep slopes
		ctu 10		15 - 50		Hill sides
st 6	Gentle sloping parts and flats in lineated metamorphic rocks		stu 11	$2\frac{1}{2}$ - 15		Gentle slopes
			stu 12	$2\frac{1}{2}$		Flats
ct 7	Scarp slope and dip slopes in limestone		stu 13	15	I - D	Scarp slope
		ctu 14		15		Dip slope
st 8	Gentle sloping parts and flats in limestone		stu 15	$2\frac{1}{2}$ - 15		Gentle slopes
			stu 16	$2\frac{1}{2}$		Flats
st 9	Unsorted material of coarse textured sediments in gravel plains with fine texture silt		stu 17	$2\frac{1}{2}$ - $7\frac{1}{2}$	II - E	Gentle slopes
			stu 18	$2\frac{1}{2}$		Flats

Table 11 continued

TYPES OF UNIT LANDFORMS

Scale 1:50,000

Landform type No.	Morphology	Types of unit landform: Complex No.	Types of unit landform: Simple No.	Approx. slope limit degrees	Landform system No.	Name
ct 10	Eolian sand dunes and dune complexes	ctu 19		7½ - 15	II - F	Gentle sloping dome shaped dunes
			stu 20	45		Sand slip faces
			stu 21	7½ - 45		Sand pack faces
st 11	Sand sheets and deflation areas		stu 22	2½		Flat sand surface
			stu 23	2½		Blow-out
st 12	Erosion slopes and gentle slopes in weakly consolidated fine textured sediments	ctu 24		15	II - G	Steep to moderate slo
			stu 25	2½ - 15		Gentle slopes
st 13	Slightly eroded flats		stu 26	2½		Flats
st 14	Erosion slopes and gentle slopes in weakly consolidated coarser textured sediments	ctu 27		15	II - H	Steep to moderate slo
			stu 28	2½ - 15		Gentle slopes
st 15	Slightly eroded flats		stu 29	2½		Flats
ct 16	Gentle sloping and flat plains with some benches		stu 30	2½ - 15	II - I	Bench slopes
			stu 31	2½ - 15		Gentle slopes
			stu 32	2½		Flats
st 17	Benches and steep slopes limestone	ctu 33		15	III - J	Steep slope benches
			stu 34	15		Dip slopes
st 18	Gentle slopes and flat limestone areas		stu 35	2½ - 15		Gentle slopes
			stu 36	2½		Flats
ct 19	Dissected tableland and pediment with drifted sand	ctu 37		15	III - K	Steep slopes
		ctu 38		2½ - 15		Pediment slopes
			stu 39	2½		Gentle slopes and fl

Table 12

Grade scale	Pipette 1		Pipette 2		Sedimentation tube	
	%	Cumulative %	%	Cumulative %	%	Cumulative %
above 1 mm	3.4	3.4	3.3	3.3	4.0	4.0
1 - ½ mm	1.9	5.3	1.8	5.1	1.6	5.6
½ - ¼ mm	2.3	7.6	2.3	7.4	2.3	7.9
¼ - ⅛ mm	2.7	10.3	2.7	10.1	2.7	10.6
⅛ - 1/16 mm	2.5	12.8	2.5	12.6	2.4	13.0
1/16 - 1/32 mm	4.1	16.9	4.6	17.12	8.4	21.4
1/32 - 1/64 mm	6.5	23.4	7.2	24.4	18.6	40.0
1/64 - 1/128	14.0	37.4	12.5	36.9	60.0*	100.0*
1/128 - 1/256	12.6	50.0	12.9	49.8	-	-
1/256 - 1/1000	22.1	72.1	24.1	73.9	-	-
under $\frac{1}{1000}$	27.9	100.0	26.1	100.0	-	-

Table No. 12. A comparison of pipette and sedimentation tube methods. after Krumbien (1932b).

* The material below 1/16 mm. was grouped into a single grade because of the difficulty of separating smaller grades.

Table 13

A comparison between results obtained by Pipette and the hydrometer-pipette methods.

Method	above 0.02 mm	0.02-0.005 mm	0.005-0.002 mm	under 0.002 mm
1- Pipette	17.8	20.0	19.2	43.0
1- Hydro-pipette	17.3	20.9	18.5	43.3
2- Pipette	27.0	29.5	9.3	34.2
2- Hydro-pipette	26.0	30.7	10.0	33.3
3- Pipette	41.2	33.8	7.7	18.3
3- Hydro-pipette	39.3	34.1	8.3	18.3
4- Pipette	23.0	29.5	13.3	34.2
4- Hydro-pipette	21.7	30.6	12.7	35.0

After Hellman and McKelney (1941).

Table 14

A comparison between results obtained by pipette and the hydrometer - pipette methods.

Method	above 1/16 mm.	1/16 - 1/32	1/32 - 1/64	1/64 - 1/128	1/128 - 1/256	1/256 - 1/512	under 1/512
1- Pipette	39.2	24.7	17.8	7.1	3.4	2.3	5.3
1- Hydro-pipette	39.0	26.4	16.6	6.7	4.5	2.0	4.5
2- Pipette	1.3	21.4	29.8	22.2	13.8	7.2	4.8
2- Hydro-pipette	0.7	19.8	29.8	23.0	14.4	7.4	4.7
3- Pipette	4.7	37.0	31.5	9.9	4.3	3.3	14.1
3- Hydro-pipette	3.5	34.0	31.5	10.6	4.0	4.0	11.0
4- Pipette	12.8	16.3	12.7	10.9	8.0	6.2	33.0
4- Hydro-pipette	10.8	20.0	13.3	10.0	10.1	6.3	29.0

(after Hellman and McKelvey, 1941).

Table 15 Shape measurements of pebbles

PEDIMENT A SITE ONE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	75.000	62.000	60.000	6.500	146084.000	3652.101	0.918	1.142	173.333	COMPACT	
2	80.000	70.000	65.000	7.500	190589.938	4398.227	0.910	1.154	187.500	COMPACT	
3	95.000	50.000	45.000	6.500	111919.188	3730.641	0.753	1.611	136.842		ELONGATED
4	90.000	70.000	60.000	9.500	197920.313	4948.008	0.830	1.333	211.111	COMPACT	ELONGATED
5	70.000	60.000	47.000	7.000	103358.375	3298.572	0.807	1.383	200.000	COMPACT	BLADED
6	44.000	39.000	33.000	9.500	29650.348	1347.743	0.859	1.258	431.818	COMPACT	
7	35.000	32.000	16.000	4.000	9382.887	879.646	0.611	2.094	228.571		PLATY
8	33.000	25.000	20.000	3.500	8639.379	647.953	0.786	1.450	212.121	COMPACT	BLADED
9	30.000	29.000	16.000	3.000	7288.492	683.296	0.665	1.844	200.000	COMPACT	PLATY
10	30.000	20.000	11.000	2.500	3455.752	471.239	0.586	2.273	166.667		BLADED
11	33.000	31.000	15.000	3.500	8034.621	803.462	0.604	2.133	212.121		PLATY
12	33.000	30.000	15.000	4.500	7775.441	777.544	0.610	2.100	272.727		PLATY
13	30.000	25.000	20.000	2.500	7853.980	589.049	0.811	1.375	166.667	COMPACT	BLADED
14	27.000	23.000	15.000	6.500	4877.320	487.732	0.713	1.667	481.481	COMPACT	BLADED
15	31.000	25.000	20.000	8.000	8115.777	608.683	0.802	1.400	516.129	COMPACT	BLADED
16	26.000	20.000	19.000	9.500	5173.152	408.407	0.885	1.211	730.769	COMPACT	
17	30.000	24.000	15.000	3.500	5654.863	565.487	0.679	1.800	233.333		BLADED
18	25.000	24.000	20.000	4.500	6283.184	471.239	0.874	1.225	360.000	COMPACT	
19	30.000	23.000	16.000	2.000	5780.527	541.925	0.719	1.656	133.333	COMPACT	BLADED
20	25.000	24.000	23.000	4.500	7225.660	471.239	0.959	1.065	360.000	COMPACT	
21	29.000	25.000	23.000	3.500	8731.008	569.414	0.900	1.174	241.379	COMPACT	
22	24.000	23.000	10.000	2.000	2890.265	433.540	0.566	2.350	166.667		PLATY
23	28.000	23.000	12.000	6.500	4046.371	505.796	0.607	2.125	464.286		PLATY
24	26.000	23.000	14.000	2.000	4383.566	469.668	0.689	1.750	153.846	COMPACT	PLATY
25	27.000	25.000	17.000	4.500	6008.293	530.144	0.754	1.529	333.333	COMPACT	PLATY
26	22.000	20.000	19.000	5.000	4377.285	345.575	0.936	1.105	454.545	COMPACT	
27	38.000	35.000	30.000	4.500	20891.590	1044.579	0.878	1.217	236.842	COMPACT	
28	39.000	38.000	26.000	3.000	20175.305	1163.960	0.770	1.481	153.846	COMPACT	PLATY
29	32.000	26.000	22.000	5.000	9583.949	653.451	0.835	1.318	312.500	COMPACT	BLADED
30	40.000	38.000	12.000	5.500	9550.441	1193.805	0.456	3.250	275.000	VERY	PLATY
31	25.000	22.000	20.000	6.500	5759.586	431.969	0.899	1.175	520.000	COMPACT	
32	40.000	39.000	37.000	8.500	30222.121	1225.221	0.957	1.068	425.000	COMPACT	
33	29.000	23.000	21.000	7.000	7334.047	523.860	0.871	1.238	482.759	COMPACT	
34	23.000	21.000	18.000	4.000	4552.164	379.347	0.875	1.222	347.826	COMPACT	
35	30.000	26.000	20.000	5.000	8168.141	612.610	0.800	1.400	333.333	COMPACT	BLADED
36	45.000	38.000	20.000	6.500	17907.078	1343.031	0.616	2.075	288.889		PLATY
37	36.000	26.000	24.000	3.500	11762.121	735.133	0.851	1.292	194.444	COMPACT	ELONGATED
38	30.000	25.000	20.000	2.500	7853.980	589.049	0.811	1.375	166.667	COMPACT	BLADED
39	43.000	39.000	31.000	6.500	27220.328	1317.113	0.831	1.323	302.325	COMPACT	
40	45.000	32.000	30.000	7.000	22619.465	1130.973	0.855	1.283	311.111	COMPACT	ELONGATED
41	35.000	31.000	20.000	4.500	11362.090	852.157	0.717	1.650	257.143	COMPACT	PLATY
42	45.000	37.000	32.000	7.500	27897.340	1307.688	0.850	1.281	333.333	COMPACT	
43	37.000	30.000	25.000	5.000	14529.863	871.792	0.826	1.340	270.270	COMPACT	BLADED
44	38.000	32.000	25.000	4.500	15917.402	955.044	0.801	1.400	236.842	COMPACT	BLADED
45	42.000	28.000	27.000	3.500	16625.305	923.628	0.853	1.296	166.667	COMPACT	ELONGATED
46	45.000	40.000	34.000	8.500	32044.242	1413.717	0.863	1.250	377.778	COMPACT	
47	52.000	40.000	35.000	9.000	38117.988	1633.628	0.838	1.314	346.154	COMPACT	ELONGATED
48	46.000	40.000	30.000	8.500	28902.652	1445.133	0.780	1.433	369.565	COMPACT	BLADED
49	50.000	45.000	40.000	5.500	47123.887	1767.146	0.893	1.188	220.000	COMPACT	
50	27.000	17.000	16.000	1.800	3845.309	360.498	0.823	1.375	133.333	COMPACT	ELONGATED
51	28.000	20.000	10.000	4.000	2932.153	439.823	0.563	2.400	285.714		BLADED
52	30.000	25.000	11.000	5.000	4319.688	589.049	0.544	2.500	333.333		PLATY
53	30.000	18.000	16.000	3.500	4523.891	424.115	0.780	1.500	233.333	COMPACT	ELONGATED
54	27.000	23.000	10.000	4.000	3251.548	487.732	0.544	2.500	296.296		PLATY
55	26.000	20.000	10.000	3.000	2722.714	408.407	0.577	2.300	230.769		BLADED
56	30.000	20.000	16.000	6.000	5026.547	471.239	0.753	1.563	400.000	COMPACT	ELONGATED
57	28.000	18.000	12.000	2.800	3166.725	395.841	0.659	1.917	200.000		BLADED
58	27.000	20.000	11.000	4.000	3110.177	424.115	0.607	2.136	296.296		BLADED
59	35.000	24.000	13.000	5.000	5717.695	659.734	0.586	2.269	285.714		BLADED
60	40.000	30.000	13.000	5.500	8168.141	942.478	0.520	2.692	275.000	VERY	BLADED
61	27.000	22.000	11.000	6.000	3421.194	466.526	0.588	2.227	444.444		PLATY
62	40.000	32.000	21.000	4.000	14074.332	1005.310	0.701	1.714	200.000	COMPACT	BLADED
63	38.000	34.000	12.000	4.500	8117.875	1014.734	0.481	3.000	236.842	VERY	PLATY
64	34.000	22.000	20.000	3.800	7833.035	587.478	0.812	1.400	223.529	COMPACT	ELONGATED
65	36.000	20.000	10.000	2.800	3769.911	565.487	0.518	2.800	155.555	VERY	BLADED
66	26.000	20.000	14.000	3.000	3811.799	408.407	0.722	1.643	230.769	COMPACT	BLADED
67	35.000	25.000	11.000	3.000	5039.637	687.223	0.517	2.727	171.429	VERY	BLADED
68	32.000	28.000	12.000	3.000	5629.730	703.717	0.544	2.500	187.500		PLATY
69	30.000	15.000	10.000	2.500	2356.194	353.429	0.605	2.250	166.667	VERY	ELONGATED
70	25.000	22.000	12.000	2.500	3455.752	431.969	0.640	1.958	200.000		PLATY
71	36.000	25.000	15.000	3.000	7068.582	706.858	0.630	2.033	166.667		BLADED
72	30.000	15.000	12.000	2.000	2827.433	353.429	0.684	1.875	133.333		ELONGATED
73	27.000	15.000	10.000	3.000	2120.575	318.086	0.627	2.100	222.222		ELONGATED
74	25.000	20.000	13.000	3.500	3403.392	392.699	0.697	1.731	280.000	COMPACT	BLADED
75	34.000	23.000	10.000	4.000	4094.542	614.181	0.504	2.850	235.294	VERY	BLADED
76	38.000	30.000	10.000	4.000	5969.023	895.354	0.444	3.400	210.526	VERY	PLATY
77	35.000	16.000	14.000	1.800	4105.012	439.823	0.705	1.821	102.857		ELONGATED
78	29.000	15.000	10.000	4.000	2277.655	341.648	0.613	2.200	275.862		ELONGATED
79	34.000	25.000	17.000	5.000	7566.000	667.588	0.698	1.735	294.117		BLADED
80	28.000	27.000	21.000	3.000	8312.652	593.761	0.836	1.310	214.286	COMPACT	
81	25.000	15.000	15.000	3.500	2945.243	294.524	0.843	1.333	280.000	COMPACT	ELONGATED
82	30.000	25.000	18.000	2.000	7068.582	589.049	0.756	1.528	133.333	COMPACT	BLADED
83	27.000	25.000	19.000	3.000	6715.152	530.144	0.812	1.368	222.222	COMPACT	
84	34.000	19.000	14.000	4.000	4735.426	507.367	0.672	1.893	235.294		ELONGATED
85	28.000	20.000	17.000	3.000	4984.660	439.823	0.802	1.412	214.286	COMPACT	ELONGATED
86	30.000	24.000	10.000	3.000	3769.911	565.487	0.518	2.700	200.000	VERY	PLATY
87	32.000	20.000	10.000	2.000	3351.032	502.655	0.539	2.600	125.000	VERY	BLADED
88	31.000	18.000	11.000	2.000	3213.849	438.252	0.601	2.227	129.032		BLADED
89	35.000	15.000	10.000	3.000	2748.894	412.334	0.575	2.500	171.429	VERY	ELONGATED
90	28.000	20.000	10.000	2.800	2932.153	439.823	0.563	2.400	200.000		BLADED
91	31.000	15.000	14.000	3.000	3408.628	365.210	0.750	1.643	193.548		ELONGATED
92	34.000	20.000	19.000	2.000	6764.895	534.071	0.810	1.421	117.647	COMPACT	ELONGATED
93	40.000	31.000	12.000	5.000	7791.148	973.894	0.488	2.958	250.000	VERY	PLATY
94	41.000	31.000	15.000	5.500	9982.410	998.241	0.561	2.400	268.292		BLADED
95	32.000	28.000	19.000	4.000	8913.742	703.717	0.739	1.579	250.000	COMPACT	PLATY
96	42.000	30.000	11.000	4.000	7257.078	989.602	0.458	3.273	190.476	VERY	BLADED
97	52.000	47.000	12.000	6.000	15356.102	1919.513	0.383	4.125	230.769	VERY	PLATY
98	45.000	40.000	16.000	4.000	15079.645	1413.717	0.522	2.656	177.778		PLATY
99	59.000	50.000	22.000	8.000	33981.559	2316.925	0.547	2.477	271.186		PLATY
100	50.000	42.000	35.000	3.500	38484.508	1649.336	0.836	1.314	140.000	COMPACT	

Table 16 Shape measurements of pebbles

PEDIMENT A SITE TWO

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	39.000	36.000	33.000	7.500	24259.375	1102.699	0.919	1.136	384.615	COMPACT	
2	34.000	31.000	25.000	5.000	13796.824	827.810	0.840	1.300	294.117	COMPACT	
3	38.000	33.000	26.000	6.000	17071.414	984.869	0.814	1.365	315.789	COMPACT	BLADED
4	30.000	29.000	19.000	4.000	8655.086	683.296	0.746	1.553	266.667	COMPACT	PLATY
5	34.000	28.000	25.000	3.500	12461.648	747.699	0.869	1.240	205.882	COMPACT	
6	36.000	30.000	28.000	4.500	15833.625	848.230	0.899	1.179	250.000	COMPACT	
7	38.000	35.000	26.000	5.000	18106.043	1044.579	0.798	1.404	263.158	COMPACT	PLATY
8	48.000	35.000	30.000	7.000	26389.375	1319.459	0.812	1.383	291.667	COMPACT	ELONGATED
9	39.000	30.000	20.000	5.000	12252.211	918.916	0.699	1.725	256.410	COMPACT	BLADED
10	37.000	35.000	28.000	4.500	18985.691	1017.091	0.846	1.286	243.243	COMPACT	
11	25.000	22.000	18.000	3.000	5183.625	431.969	0.838	1.306	240.000	COMPACT	
12	29.000	20.000	19.000	6.000	5770.055	455.531	0.854	1.289	413.793	COMPACT	ELONGATED
13	35.000	30.000	20.000	6.500	10995.574	824.668	0.725	1.625	371.428	COMPACT	BLADED
14	30.000	26.000	25.000	4.500	10210.176	612.610	0.921	1.120	300.000	COMPACT	
15	29.000	27.000	21.000	4.000	8609.531	614.967	0.826	1.333	275.862	COMPACT	
16	26.000	20.000	18.000	3.500	4900.883	408.407	0.854	1.278	269.231	COMPACT	ELONGATED
17	50.000	36.000	35.000	7.500	32986.723	1413.717	0.880	1.229	300.000	COMPACT	
18	40.000	38.000	31.000	7.000	24671.973	1193.805	0.858	1.258	350.000	COMPACT	
19	39.000	36.000	27.000	6.000	19848.582	1102.699	0.804	1.389	307.692	COMPACT	PLATY
20	35.000	23.000	20.000	4.500	8429.938	632.245	0.792	1.450	257.143	COMPACT	ELONGATED
21	30.000	26.000	21.000	5.000	8576.547	612.610	0.827	1.333	333.333	COMPACT	
22	40.000	24.000	20.000	3.500	10053.094	753.982	0.747	1.600	175.000		ELONGATED
23	27.000	26.000	25.000	6.500	9189.156	551.349	0.962	1.060	481.481	COMPACT	
24	26.000	25.000	20.000	3.500	6806.781	510.509	0.851	1.275	269.231	COMPACT	
25	55.000	45.000	20.000	7.000	25918.137	1943.860	0.545	2.500	254.545		PLATY
26	45.000	43.000	41.000	9.500	41539.707	1519.745	0.954	1.073	422.222	COMPACT	
27	30.000	25.000	23.000	8.500	9032.078	589.049	0.890	1.196	566.667	COMPACT	
28	41.000	35.000	33.000	9.000	24795.020	1127.046	0.912	1.152	439.024	COMPACT	
29	40.000	29.000	28.000	4.500	17006.484	911.062	0.878	1.232	225.000	COMPACT	
30	37.000	23.000	20.000	6.500	8911.648	668.374	0.778	1.500	351.351	COMPACT	ELONGATED
31	38.000	31.000	26.000	7.000	16036.781	925.199	0.831	1.327	368.421	COMPACT	BLADED
32	32.000	28.000	27.000	8.000	12666.898	703.717	0.934	1.111	500.000	COMPACT	
33	35.000	29.000	27.000	4.500	14349.223	797.179	0.896	1.185	257.143	COMPACT	
34	41.000	30.000	27.000	3.500	17388.715	966.040	0.840	1.315	170.732	COMPACT	ELONGATED
35	39.000	30.000	24.000	6.000	14702.652	918.916	0.790	1.438	307.692	COMPACT	BLADED
36	39.000	30.000	25.000	7.500	15315.262	918.916	0.811	1.380	384.615	COMPACT	BLADED
37	35.000	25.000	15.000	3.500	6872.230	687.223	0.636	2.000	200.000		BLADED
38	34.000	25.000	15.000	3.000	6675.883	667.588	0.642	1.967	176.471		BLADED
39	21.000	26.000	23.000	5.000	6575.352	428.827	0.990	1.022	476.190	COMPACT	
40	30.000	25.000	24.000	6.500	9424.777	589.049	0.916	1.146	433.333	COMPACT	
41	43.000	37.000	35.000	7.500	29156.598	1249.568	0.917	1.143	348.837	COMPACT	
42	41.000	35.000	26.000	5.000	19535.469	1127.045	0.778	1.462	243.902	COMPACT	BLADED
43	40.000	30.000	24.000	6.500	15079.645	942.478	0.783	1.458	325.000	COMPACT	BLADED
44	40.000	35.000	30.000	9.500	21991.148	1099.557	0.863	1.250	475.000	COMPACT	
45	30.000	28.000	25.000	7.000	10995.574	659.734	0.905	1.160	466.667	COMPACT	
46	30.000	29.000	25.000	4.500	11388.270	683.296	0.896	1.180	300.000	COMPACT	
47	31.000	28.000	27.000	5.000	12271.059	681.726	0.943	1.093	322.581	COMPACT	
48	30.000	22.000	20.000	4.500	6911.500	518.363	0.846	1.300	300.000	COMPACT	ELONGATED
49	40.000	27.000	8.000	0.800	4523.891	848.230	0.390	4.188	40.000	VERY	BLADED
50	28.000	24.000	19.000	6.000	6685.309	527.787	0.813	1.368	428.571	COMPACT	BLADED
51	43.000	34.000	16.000	3.800	12248.020	1148.252	0.559	2.406	176.744		BLADED
52	40.000	25.000	20.000	3.000	10471.973	785.398	0.737	1.625	150.000		ELONGATED
53	45.000	25.000	18.000	3.000	10602.875	883.573	0.660	1.944	133.333		ELONGATED
54	36.000	30.000	10.000	4.000	5654.863	848.230	0.452	3.300	222.222	VERY	PLATY
55	35.000	20.000	10.000	4.000	3665.191	549.779	0.523	2.750	228.571	VERY	BLADED
56	40.000	34.000	18.000	3.000	12817.695	1068.141	0.620	2.056	150.000		PLATY
57	34.000	20.000	10.000	2.800	3560.471	534.071	0.528	2.700	164.706	VERY	BLADED
58	37.000	35.000	13.000	7.000	8814.785	1017.091	0.507	2.769	378.378		PLATY
59	34.000	27.000	15.000	3.800	7209.953	720.995	0.626	2.033	223.529		BLADED
60	38.000	16.000	14.000	2.800	4456.871	477.522	0.685	1.929	147.368		ELONGATED
61	45.000	30.000	10.000	3.000	7068.582	1060.287	0.420	3.750	133.333	VERY	BLADED
62	32.000	20.000	12.000	2.000	4021.239	502.655	0.608	2.167	125.000		BLADED
63	31.000	28.000	11.000	2.500	4999.320	681.726	0.519	2.682	161.290		PLATY
64	25.000	16.000	11.000	2.000	2303.834	314.159	0.671	1.864	160.000		BLADED
65	32.000	26.000	14.000	3.000	6098.875	653.451	0.618	2.071	187.500		BLADED
66	34.000	15.000	11.000	1.800	2937.389	400.553	0.619	2.227	105.882	VERY	ELONGATED
67	25.000	15.000	12.000	4.000	2356.194	294.524	0.727	1.667	320.000		ELONGATED
68	30.000	20.000	11.000	2.000	3455.752	471.239	0.586	2.273	133.333		BLADED
69	25.000	15.000	10.000	4.000	1963.495	294.524	0.644	2.000	320.000		ELONGATED
70	45.000	34.000	12.000	4.000	9613.273	1201.659	0.455	3.292	177.778	VERY	BLADED
71	32.000	25.000	18.000	4.500	7539.820	628.318	0.740	1.583	281.250	COMPACT	BLADED
72	35.000	22.000	14.000	3.500	5644.395	604.756	0.634	2.036	200.000		BLADED
73	38.000	32.000	12.000	4.000	7640.352	955.044	0.491	2.917	210.526	VERY	PLATY
74	43.000	30.000	15.000	5.000	10131.633	1013.164	0.559	2.433	232.558		BLADED
75	29.000	17.000	16.000	4.000	4130.145	387.201	0.804	1.438	275.862	COMPACT	ELONGATED
76	34.000	15.000	12.000	2.000	3204.424	400.553	0.656	2.042	117.647		ELONGATED
77	32.000	30.000	11.000	4.000	5529.199	753.982	0.501	2.818	250.000		PLATY
78	40.000	26.000	11.000	3.000	5989.969	816.814	0.488	3.000	150.000	VERY	BLADED
79	30.000	25.000	15.000	2.500	5890.484	589.049	0.669	1.833	166.667		BLADED
80	26.000	19.000	10.000	3.000	2586.578	387.987	0.587	2.250	230.769		BLADED
81	35.000	27.000	15.000	2.000	7422.012	742.201	0.620	2.067	114.286		BLADED
82	30.000	27.000	16.000	4.000	6785.840	636.172	0.681	1.781	266.667	COMPACT	PLATY
83	40.000	20.000	10.000	3.800	4188.789	628.318	0.500	3.000	190.000	VERY	ELONGATED
84	32.000	25.000	15.000	5.000	6283.184	628.318	0.655	1.900	312.500		BLADED
85	25.000	23.000	19.000	4.000	5720.316	451.604	0.856	1.263	320.000	COMPACT	
86	27.000	25.000	14.000	3.800	4948.008	530.144	0.662	1.857	281.481	COMPACT	PLATY
87	31.000	25.000	19.000	3.000	7709.988	608.583	0.775	1.474	193.548	COMPACT	BLADED
88	40.000	27.000	18.000	2.500	10178.758	848.230	0.669	1.861	125.000		BLADED
89	25.000	17.000	10.000	3.000	2225.295	333.794	0.617	2.100	240.000		BLADED
90	31.000	27.000	19.000	2.000	8326.789	657.378	0.756	1.526	129.032	COMPACT	BLADED
91	44.000	30.000	10.000	3.000	6911.500	1036.725	0.423	3.700	136.364	VERY	BLADED
92	30.000	20.000	10.000	4.500	3141.593	471.239	0.550	2.500	300.000	VERY	BLADED
93	38.000	25.000	12.000	3.000	5969.023	746.128	0.533	2.625	157.895	VERY	BLADED
94	31.000	30.000	14.000	3.000	6817.254	730.420	0.595	2.179	193.548		PLATY
95	38.000	20.000	10.000	3.000	3979.351	596.903	0.509	2.900	157.895	VERY	BLADED
96	38.000	37.000	11.000	5.000	8097.977	1104.270	0.442	3.409	263.158	VERY	PLATY
97	25.000	18.000	17.000	3.000	4005.531	353.429	0.863	1.265	240.000	COMPACT	ELONGATED
98	30.000	17.000	13.000	2.800	3471.460	400.553	0.692	1.808	186.667		ELONGATED
99	24.000	20.000	18.000	6.500	4523.891	376.991	0.877	1.222	541.667	COMPACT	
100	40.000	20.000	15.000	3.000	6283.184	628.318	0.655	2.000	150.000		ELONGATED

Table 17 Shape measurements of pebbles

PEDIMENT A SITE THREE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	30.000	25.000	20.000	3.500	7853.980	589.049	0.811	1.375	233.333	COMPACT	BLADED
2	40.000	35.000	30.000	8.500	21991.148	1099.557	0.863	1.250	425.000	COMPACT	
3	35.000	30.000	28.000	9.500	15393.801	824.668	0.907	1.161	542.857	COMPACT	
4	45.000	40.000	35.000	9.000	32986.723	1413.717	0.893	1.214	400.000	COMPACT	
5	38.000	36.000	32.000	8.000	22921.059	1074.425	0.908	1.156	421.052	COMPACT	
6	30.000	29.000	22.000	6.500	10021.680	683.296	0.822	1.341	433.333	COMPACT	
7	40.000	35.000	27.000	7.000	19792.031	1099.557	0.805	1.389	350.000	COMPACT	BLADED
8	31.000	30.000	28.000	4.500	13634.512	730.420	0.945	1.089	290.323	COMPACT	
9	31.000	30.000	25.000	5.000	12173.668	730.420	0.876	1.220	322.581	COMPACT	
10	32.000	28.000	22.000	6.000	10321.176	703.717	0.814	1.364	375.000	COMPACT	BLADED
11	34.000	30.000	26.000	7.000	13885.836	801.106	0.872	1.231	411.765	COMPACT	
12	27.000	24.000	23.000	9.000	7803.715	508.938	0.935	1.109	666.667	COMPACT	
13	30.000	25.000	20.000	2.500	7853.980	589.049	0.811	1.375	166.667	COMPACT	BLADED
14	31.000	30.000	29.000	6.500	14121.457	730.420	0.967	1.052	419.355	COMPACT	
15	50.000	30.000	20.000	4.500	15707.961	1178.097	0.644	2.000	180.000		ELONGATED
16	28.000	23.000	12.000	5.000	4046.371	505.796	0.607	2.125	357.143		PLATY
17	32.000	28.000	24.000	2.500	11259.465	703.717	0.863	1.250	156.250	COMPACT	
18	30.000	25.000	20.000	7.000	7853.980	589.049	0.811	1.375	466.667	COMPACT	BLADED
19	30.000	25.000	20.000	4.000	7853.980	589.049	0.811	1.375	266.667	COMPACT	BLADED
20	30.000	29.000	24.000	6.500	10932.742	683.296	0.872	1.229	433.333	COMPACT	
21	35.000	33.000	27.000	7.000	16328.426	907.135	0.858	1.259	400.000	COMPACT	
22	44.000	40.000	20.000	2.500	18430.676	1382.301	0.610	2.100	113.636		PLATY
23	35.000	27.000	25.000	3.500	12370.020	742.201	0.871	1.240	200.000	COMPACT	
24	32.000	27.000	23.000	3.000	10404.953	678.584	0.849	1.283	187.500	COMPACT	
25	28.000	25.000	20.000	7.500	7330.383	549.779	0.830	1.325	535.714	COMPACT	
26	40.000	36.000	27.000	8.000	20357.520	1130.973	0.797	1.407	400.000	COMPACT	PLATY
27	28.000	25.000	24.000	4.500	8796.457	549.779	0.937	1.104	321.428	COMPACT	
28	43.000	37.000	34.000	9.500	28323.551	1249.568	0.899	1.176	441.860	COMPACT	
29	40.000	38.000	24.000	7.000	19100.883	1193.805	0.724	1.625	350.000	COMPACT	PLATY
30	45.000	40.000	25.000	4.500	23561.941	1413.717	0.703	1.700	200.000	COMPACT	PLATY
31	36.000	33.000	30.000	3.500	18661.059	933.053	0.912	1.150	194.444	COMPACT	
32	35.000	30.000	25.000	6.500	13744.465	824.668	0.841	1.300	371.428	COMPACT	
33	40.000	35.000	34.000	7.000	24923.301	1099.557	0.938	1.103	350.000	COMPACT	
34	34.000	30.000	20.000	2.500	10681.414	801.106	0.732	1.600	147.059	COMPACT	PLATY
35	37.000	35.000	30.000	9.000	20341.809	1017.091	0.886	1.200	486.486	COMPACT	
36	34.000	30.000	27.000	7.500	14419.910	801.106	0.894	1.185	441.176	COMPACT	
37	38.000	30.000	16.000	6.000	9550.441	895.354	0.608	2.125	315.789		BLADED
38	45.000	36.000	30.000	9.500	25446.898	1272.345	0.822	1.350	422.222	COMPACT	BLADED
39	32.000	30.000	20.000	3.500	10053.094	753.982	0.747	1.550	218.750	COMPACT	PLATY
40	31.000	28.000	27.000	2.000	12271.059	681.726	0.943	1.093	129.032	COMPACT	
41	25.000	23.000	16.000	4.000	4817.105	451.604	0.764	1.500	320.000	COMPACT	PLATY
42	32.000	26.000	24.000	6.500	10455.219	653.451	0.885	1.208	406.250	COMPACT	
43	34.000	20.000	15.000	5.500	5340.707	534.071	0.692	1.800	323.529		ELONGATED
44	25.000	23.000	15.000	5.000	4516.039	451.604	0.731	1.600	400.000	COMPACT	PLATY
45	30.000	26.000	20.000	4.500	8168.141	612.610	0.800	1.400	300.000	COMPACT	BLADED
46	25.000	21.000	15.000	3.500	4123.340	412.334	0.754	1.533	280.000	COMPACT	BLADED
47	45.000	34.000	30.000	9.500	24033.184	1201.659	0.838	1.317	422.222	COMPACT	ELONGATED
48	32.000	27.000	25.000	7.000	11309.730	678.584	0.898	1.180	437.500	COMPACT	
49	30.000	24.000	16.000	5.000	6031.855	565.487	0.708	1.688	333.333	COMPACT	BLADED
50	30.000	24.000	13.000	5.000	4900.883	565.487	0.617	2.077	333.333		BLADED
51	30.000	20.000	10.000	2.800	3141.593	471.239	0.550	2.500	186.667	VERY	BLADED
52	31.000	28.000	18.000	5.000	8180.707	681.726	0.720	1.639	322.581	COMPACT	PLATY
53	30.000	22.000	15.000	2.800	5183.625	518.363	0.699	1.733	186.667		BLADED
54	40.000	20.000	10.000	4.000	4188.789	628.318	0.500	3.000	200.000	VERY	ELONGATED
55	30.000	25.000	17.000	3.000	6675.883	589.049	0.728	1.618	200.000	COMPACT	BLADED
56	30.000	28.000	10.000	2.000	4398.227	659.734	0.492	2.900	133.333	VERY	PLATY
57	32.000	26.000	12.000	4.000	5227.609	653.451	0.557	2.417	250.000		PLATY
58	45.000	34.000	18.000	7.000	14419.910	1201.659	0.596	2.194	311.111		BLADED
59	38.000	26.000	11.000	3.000	5690.469	775.973	0.497	2.909	157.895	VERY	BLADED
60	30.000	25.000	12.000	4.000	4712.387	589.049	0.577	2.292	266.667		PLATY
61	41.000	33.000	15.000	5.000	10626.434	1062.644	0.550	2.467	243.902		PLATY
62	40.000	28.000	12.000	5.000	7037.164	879.646	0.505	2.833	250.000	VERY	BLADED
63	37.000	20.000	15.000	2.500	5811.945	581.195	0.672	1.900	135.135		ELONGATED
64	32.000	28.000	11.000	3.000	5160.586	703.717	0.513	2.727	187.500		PLATY
65	35.000	28.000	12.000	2.500	6157.520	769.690	0.528	2.625	142.857		PLATY
66	39.000	30.000	21.000	3.500	12864.820	918.916	0.722	1.643	179.487	COMPACT	BLADED
67	39.000	25.000	18.000	3.000	9189.156	765.763	0.693	1.778	153.846		ELONGATED
68	35.000	15.000	12.000	4.000	3298.672	412.334	0.650	2.083	228.571		ELONGATED
69	34.000	25.000	19.000	3.500	8456.117	667.588	0.752	1.553	205.882	COMPACT	BLADED
70	27.000	23.000	12.000	3.000	3901.858	487.732	0.614	2.083	222.222		PLATY
71	43.000	35.000	13.000	3.500	10244.207	1182.024	0.482	3.000	162.791	VERY	PLATY
72	41.000	35.000	15.000	4.500	11270.461	1127.046	0.539	2.533	219.512		PLATY
73	40.000	24.000	11.000	5.000	5529.199	753.982	0.501	2.909	250.000	VERY	BLADED
74	40.000	30.000	17.000	3.000	10681.414	942.478	0.622	2.059	150.000		BLADED
75	31.000	27.000	14.000	4.000	6135.527	657.378	0.615	2.071	258.064		PLATY
76	30.000	20.000	16.000	3.500	5026.547	471.239	0.753	1.563	233.333	COMPACT	ELONGATED
77	24.000	20.000	15.000	4.500	3769.911	376.991	0.777	1.467	375.000	COMPACT	BLADED
78	30.000	20.000	11.000	5.000	3455.752	471.239	0.585	2.273	333.333		BLADED
79	40.000	30.000	17.000	6.000	10681.414	942.478	0.622	2.059	300.000		BLADED
80	35.000	30.000	12.000	3.800	6597.344	824.658	0.515	2.708	217.143		PLATY
81	45.000	35.000	24.000	3.800	19792.031	1237.002	0.715	1.667	168.889	COMPACT	BLADED
82	38.000	32.000	14.000	7.000	8913.742	955.044	0.544	2.500	368.421		PLATY
83	40.000	27.000	13.000	4.000	7351.324	848.230	0.539	2.577	200.000	VERY	BLADED
84	31.000	25.000	18.000	6.000	7304.199	608.683	0.748	1.556	387.097	COMPACT	BLADED
85	32.000	22.000	13.000	6.000	4791.973	552.920	0.621	2.077	375.000		BLADED
86	34.000	26.000	13.000	7.000	6017.195	694.292	0.576	2.308	411.765		BLADED
87	27.000	24.000	12.000	6.000	4071.504	508.938	0.606	2.125	444.444		PLATY
88	30.000	20.000	16.000	6.000	5026.547	471.239	0.753	1.563	400.000	COMPACT	ELONGATED
89	31.000	30.000	15.000	8.000	7304.199	730.420	0.623	2.033	516.129		PLATY
90	50.000	20.000	11.000	2.000	5759.586	785.398	0.493	3.182	80.000	VERY	ELONGATED
91	32.000	24.000	13.000	3.600	5227.609	603.186	0.604	2.154	225.000		BLADED
92	30.000	20.000	14.000	4.000	4398.227	471.239	0.689	1.786	266.667		BLADED
93	35.000	27.000	13.000	3.000	6432.410	742.201	0.563	2.385	171.429		BLADED
94	44.000	20.000	20.000	4.000	9215.336	691.150	0.769	1.600	181.818		ELONGATED
95	35.000	25.000	11.000	3.000	5039.637	687.223	0.517	2.727	171.429	VERY	BLADED
96	32.000	27.000	12.000	2.000	5428.672	678.584	0.553	2.458	125.000		PLATY
97	28.000	20.000	18.000	2.000	5277.875	439.823	0.833	1.333	142.857	COMPACT	ELONGATED
98	41.000	27.000	12.000	2.800	6955.484	869.436	0.507	2.833	136.585	VERY	BLADED
99	35.000	32.000	22.000	6.500	12901.473	879.645	0.756	1.523	371.428	COMPACT	PLATY
100	38.000	36.000	32.000	8.500	22921.059	1074.425	0.908	1.156	447.368	COMPACT	

Table 18 Shape measurements of pebbles

PEDIMENT A SITE FOUR

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	43.000	31.000	30.000	8.000	20938.715	1046.936	0.877	1.233	372.093	COMPACT	ELONGATED
2	29.000	27.000	17.000	3.500	7789.578	614.967	0.773	1.474	241.379	COMPACT	PLATY
3	34.000	30.000	15.000	5.000	8011.059	801.106	0.654	2.133	294.117		PLATY
4	32.000	30.000	25.000	7.500	12566.367	753.982	0.867	1.240	468.750	COMPACT	
5	40.000	36.000	26.000	6.000	19603.535	1130.973	0.777	1.462	300.000	COMPACT	PLATY
6	30.000	25.000	23.000	5.000	9032.078	589.049	0.890	1.196	333.333	COMPACT	
7	26.000	22.000	19.000	7.500	5690.469	449.248	0.858	1.263	576.923	COMPACT	
8	35.000	30.000	27.000	5.500	14844.023	824.668	0.885	1.204	314.286	COMPACT	
9	30.000	26.000	20.000	6.000	8168.141	612.610	0.800	1.400	400.000	COMPACT	BLADED
10	30.000	25.000	23.000	5.000	9032.078	589.049	0.890	1.196	333.333	COMPACT	
11	26.000	22.000	19.000	7.500	5690.469	449.248	0.858	1.263	576.923	COMPACT	
12	35.000	30.000	27.000	5.500	14844.023	824.668	0.885	1.204	314.286	COMPACT	
13	30.000	29.000	27.000	7.000	12299.332	683.296	0.943	1.093	466.667	COMPACT	
14	40.000	34.000	20.000	8.500	14241.883	1068.141	0.665	1.850	425.000		PLATY
15	32.000	30.000	25.000	9.000	12566.367	753.982	0.867	1.240	562.500	COMPACT	
16	25.000	23.000	20.000	9.500	6021.383	451.504	0.885	1.200	760.000	COMPACT	
17	27.000	25.000	24.000	2.500	8482.297	530.144	0.949	1.083	185.185	COMPACT	
18	31.000	25.000	24.000	3.000	9738.934	608.683	0.935	1.167	193.548	COMPACT	
19	40.000	34.000	27.000	4.500	19226.547	1068.141	0.812	1.370	225.000	COMPACT	BLADED
20	25.000	20.000	17.000	5.000	4450.586	392.699	0.833	1.324	400.000	COMPACT	BLADED
21	31.000	30.000	27.000	8.500	13147.563	730.420	0.922	1.130	548.387	COMPACT	
22	44.000	35.000	30.000	9.000	24190.262	1209.513	0.836	1.317	409.091	COMPACT	BLADED
23	38.000	30.000	25.000	7.500	14922.563	895.354	0.818	1.360	394.737	COMPACT	BLADED
24	31.000	30.000	25.000	6.000	12173.668	730.420	0.875	1.220	387.097	COMPACT	
25	38.000	30.000	20.000	4.500	11938.051	895.354	0.705	1.700	236.842	COMPACT	BLADED
26	38.000	37.000	36.000	7.000	26502.473	1104.270	0.973	1.042	368.421	COMPACT	
27	25.000	23.000	18.000	8.000	5419.246	451.604	0.826	1.333	640.000	COMPACT	
28	30.000	27.000	20.000	9.500	8482.297	636.172	0.790	1.425	633.333	COMPACT	PLATY
29	30.000	29.000	17.000	9.500	7744.023	683.296	0.693	1.735	633.333	COMPACT	PLATY
30	27.000	21.000	17.000	8.000	5046.965	445.321	0.799	1.412	592.593	COMPACT	BLADED
31	29.000	23.000	15.000	7.500	5238.605	523.860	0.696	1.733	517.241	COMPACT	BLADED
32	28.000	23.000	20.000	6.000	6743.949	505.796	0.853	1.275	428.571	COMPACT	
33	30.000	26.000	25.000	7.500	10210.176	612.610	0.929	1.120	500.000	COMPACT	
34	30.000	25.000	18.000	9.000	7068.582	589.049	0.756	1.528	600.000	COMPACT	BLADED
35	27.000	23.000	20.000	5.500	6503.094	487.732	0.864	1.250	407.407	COMPACT	
36	26.000	22.000	20.000	4.000	5989.969	449.248	0.888	1.200	307.692	COMPACT	
37	30.000	26.000	25.000	7.500	10210.176	612.610	0.929	1.120	500.000	COMPACT	
38	30.000	25.000	18.000	9.000	7068.582	589.049	0.756	1.528	600.000	COMPACT	BLADED
39	27.000	23.000	20.000	5.400	6503.094	487.732	0.864	1.250	400.000	COMPACT	
40	27.000	26.000	20.000	7.500	7351.324	551.349	0.829	1.325	555.555	COMPACT	
41	35.000	30.000	24.000	6.500	13194.688	824.668	0.819	1.354	371.428	COMPACT	BLADED
42	40.000	34.000	30.000	4.000	21362.828	1068.141	0.871	1.233	200.000	COMPACT	
43	27.000	25.000	22.000	9.500	7775.441	530.144	0.895	1.182	703.704	COMPACT	
44	40.000	36.000	32.000	3.500	24127.430	1130.973	0.893	1.188	175.000	COMPACT	
45	38.000	37.000	34.000	2.000	25030.113	1104.270	0.937	1.103	105.263	COMPACT	
46	34.000	32.000	22.000	8.000	12532.859	854.513	0.763	1.500	470.588	COMPACT	PLATY
47	36.000	26.000	20.000	7.500	9801.766	735.133	0.753	1.550	416.667	COMPACT	BLADED
48	26.000	23.000	20.000	6.000	6262.238	469.668	0.875	1.225	461.538	COMPACT	
49	29.000	21.000	11.000	9.000	3507.588	478.307	0.584	2.273	620.689		BLADED
50	25.000	20.000	12.000	8.000	3141.593	392.699	0.660	1.875	640.000		BLADED
51	23.000	21.000	11.000	8.000	2781.880	379.347	0.630	2.000	695.652		PLATY
52	45.000	20.000	17.000	9.000	8011.059	706.858	0.685	1.912	400.000		ELONGATED
53	36.000	24.000	11.000	9.500	4976.281	678.584	0.519	2.727	527.778	VERY	BLADED
54	30.000	20.000	12.000	9.000	3769.911	471.239	0.621	2.083	600.000		BLADED
55	43.000	39.000	15.000	6.000	13171.125	1317.113	0.512	2.733	279.070		PLATY
56	45.000	30.000	18.000	6.000	12723.449	1060.287	0.621	2.083	266.667		BLADED
57	35.000	20.000	15.000	5.000	5497.785	549.779	0.685	1.833	285.714		ELONGATED
58	45.000	32.000	30.000	8.000	22619.465	1130.973	0.855	1.283	355.555	COMPACT	ELONGATED
59	37.000	25.000	18.000	4.000	8717.918	726.493	0.705	1.722	216.216		BLADED
60	38.000	32.000	27.000	4.000	17190.793	955.044	0.843	1.296	210.526	COMPACT	
61	42.000	28.000	18.000	4.000	11083.535	923.628	0.651	1.944	190.476		BLADED
62	45.000	40.000	23.000	6.000	21676.988	1413.717	0.665	1.848	266.667	COMPACT	PLATY
63	52.000	40.000	13.000	5.000	14158.109	1633.628	0.433	3.538	192.308	VERY	PLATY
64	46.000	30.000	19.000	3.000	13728.758	1083.849	0.640	2.000	130.435		BLADED
65	50.000	35.000	23.000	6.000	21074.848	1374.447	0.671	1.848	240.000		BLADED
66	54.000	30.000	16.000	6.000	13571.680	1272.345	0.541	2.625	222.222	VERY	BLADED
67	39.000	36.000	15.000	4.000	11026.988	1102.699	0.543	2.500	205.128		PLATY
68	34.000	25.000	13.000	3.500	5785.766	667.588	0.584	2.269	205.882		BLADED
69	38.000	26.000	18.000	3.000	9311.680	775.973	0.690	1.778	157.895		BLADED
70	30.000	19.000	15.000	4.000	4476.770	447.677	0.734	1.633	266.667		ELONGATED
71	34.000	28.000	11.000	4.300	5483.125	747.699	0.503	2.818	252.941	VERY	PLATY
72	36.000	30.000	18.000	3.800	10178.758	848.230	0.659	1.833	211.111		BLADED
73	38.000	26.000	20.000	3.000	10346.309	775.973	0.740	1.600	157.895	COMPACT	ELONGATED
74	48.000	25.000	24.000	4.800	15079.645	942.478	0.783	1.521	200.000		ELONGATED
75	39.000	30.000	12.000	2.800	7351.324	918.916	0.497	2.875	143.590	VERY	BLADED
76	37.000	28.000	10.000	5.000	5424.480	813.672	0.459	3.250	270.270	VERY	BLADED
77	25.000	18.000	11.000	6.000	2591.814	353.429	0.645	1.955	480.000		BLADED
78	29.000	20.000	13.000	3.000	3947.935	455.531	0.663	1.885	206.897		BLADED
79	35.000	30.000	14.000	4.000	7696.898	824.668	0.572	2.321	228.571		PLATY
80	28.000	21.000	14.000	2.000	4310.262	461.814	0.693	1.750	142.857		BLADED
81	26.000	18.000	16.000	5.000	3920.708	367.566	0.818	1.375	384.615	COMPACT	ELONGATED
82	50.000	35.000	17.000	5.000	15577.063	1374.447	0.549	2.500	200.000		BLADED
83	40.000	38.000	12.000	2.400	9550.441	1193.805	0.456	3.250	120.000	VERY	PLATY
84	35.000	20.000	17.000	2.000	6230.824	549.779	0.745	1.618	114.286		ELONGATED
85	40.000	24.000	15.000	6.000	7539.820	753.982	0.617	2.133	300.000		BLADED
86	27.000	25.000	11.000	6.000	3887.721	530.144	0.564	2.364	444.444		PLATY
87	26.000	25.000	10.000	4.000	3403.392	510.509	0.536	2.550	307.692		PLATY
88	55.000	28.000	18.000	3.500	14514.156	1209.513	0.595	2.306	127.273	VERY	ELONGATED
89	39.000	26.000	14.000	9.000	7433.008	796.394	0.578	2.321	461.538		BLADED
90	38.000	34.000	18.000	9.500	12176.813	1014.734	0.631	2.000	500.000		PLATY
91	27.000	25.000	17.000	9.000	6008.293	530.144	0.754	1.529	666.667	COMPACT	PLATY
92	40.000	39.000	15.000	9.000	12252.211	1225.221	0.524	2.633	450.000		PLATY
93	30.000	21.000	14.000	3.200	4618.141	494.801	0.678	1.821	213.333		BLADED
94	38.000	27.000	18.000	4.500	9669.820	805.818	0.681	1.806	236.842		BLADED
95	30.000	25.000	19.000	4.500	7461.281	589.049	0.784	1.447	300.000	COMPACT	BLADED
96	30.000	20.000	10.000	8.000	3141.593	471.239	0.550	2.500	533.333	VERY	BLADED
97	22.000	15.000	10.000	2.500	1727.876	259.181	0.672	1.850	227.273		BLADED
98	40.000	22.000	13.000	6.000	5989.969	691.150	0.577	2.385	300.000	VERY	ELONGATED
99	28.000	26.000	19.000	9.500	7242.418	571.770	0.792	1.421	678.571	COMPACT	PLATY
100	32.000	30.000	28.000	8.000	14074.332	753.982	0.935	1.107	500.000	COMPACT	

Table 19 Shape measurements of pebbles

(II-21)

PEDIMENT A SITE FIVE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	54.000	32.000	30.000	4.500	27143.359	1357.168	0.805	1.433	166.667	COMPACT	ELONGATED
2	32.000	25.000	14.000	5.500	5864.305	628.318	0.626	2.036	343.750		BLADED
3	35.000	30.000	25.000	6.500	13744.465	824.668	0.841	1.300	371.428	COMPACT	
4	30.000	25.000	15.000	7.500	5890.484	589.049	0.669	1.833	500.000		BLADED
5	35.000	27.000	22.000	4.500	10885.617	742.201	0.800	1.409	257.143	COMPACT	BLADED
6	36.000	26.000	25.000	2.000	12252.211	735.133	0.874	1.240	111.111	COMPACT	ELONGATED
7	30.000	22.000	15.000	3.500	5183.625	518.363	0.699	1.733	233.333		BLADED
8	27.000	25.000	15.000	7.500	5301.438	530.144	0.693	1.733	555.555	COMPACT	PLATY
9	25.000	23.000	20.000	9.000	6021.383	451.604	0.886	1.200	720.000	COMPACT	
10	34.000	30.000	23.000	3.500	12283.625	801.106	0.803	1.391	205.882	COMPACT	BLADED
11	38.000	32.000	30.000	2.000	19100.883	955.044	0.905	1.167	105.263	COMPACT	
12	35.000	30.000	16.000	4.500	8796.457	824.668	0.625	2.031	257.143		PLATY
13	29.000	25.000	15.000	2.500	5694.133	569.414	0.677	1.800	172.414	COMPACT	PLATY
14	34.000	31.000	25.000	2.000	13796.824	827.810	0.840	1.300	117.647	COMPACT	
15	28.000	27.000	22.000	3.000	8708.492	593.761	0.862	1.250	214.286	COMPACT	
16	25.000	20.000	15.000	4.500	3926.991	392.699	0.766	1.500	360.000	COMPACT	BLADED
17	30.000	28.000	25.000	3.000	10995.574	659.734	0.905	1.160	200.000	COMPACT	
18	27.000	25.000	24.000	6.000	8482.297	530.144	0.949	1.083	444.444	COMPACT	
19	34.000	26.000	19.000	4.500	8794.363	694.292	0.742	1.579	264.706	COMPACT	BLADED
20	28.000	22.000	20.000	2.000	6450.734	483.805	0.866	1.250	142.857	COMPACT	
21	30.000	27.000	24.000	3.500	10178.758	636.172	0.893	1.188	233.333	COMPACT	
22	32.000	24.000	20.000	5.000	8042.477	603.186	0.805	1.400	312.500	COMPACT	ELONGATED
23	31.000	20.000	15.000	6.000	4869.465	486.947	0.713	1.700	387.097		ELONGATED
24	35.000	30.000	15.000	8.000	8246.680	824.668	0.598	2.167	457.143		PLATY
25	28.000	20.000	19.000	7.500	5571.090	439.823	0.864	1.263	535.714	COMPACT	ELONGATED
26	31.000	20.000	18.000	6.500	5843.359	486.947	0.805	1.417	419.355	COMPACT	ELONGATED
27	34.000	30.000	20.000	7.500	10681.414	801.106	0.732	1.600	441.176	COMPACT	PLATY
28	35.000	31.000	21.000	8.500	11930.195	852.157	0.741	1.571	485.714	COMPACT	PLATY
29	40.000	33.000	21.000	5.500	14514.156	1036.725	0.694	1.738	275.000	COMPACT	BLADED
30	32.000	27.000	19.000	9.500	8595.395	678.584	0.748	1.553	593.750	COMPACT	BLADED
31	24.000	20.000	17.000	7.500	4272.563	376.991	0.844	1.294	625.000	COMPACT	
32	33.000	31.000	21.000	5.000	11248.469	803.462	0.755	1.524	303.030	COMPACT	PLATY
33	32.000	26.000	22.000	6.000	9583.949	653.451	0.835	1.318	375.000	COMPACT	BLADED
34	34.000	31.000	28.000	8.500	15452.445	827.810	0.905	1.161	500.000	COMPACT	
35	40.000	34.000	25.000	5.500	17802.355	1068.141	0.772	1.480	275.000	COMPACT	BLADED
36	31.000	27.000	26.000	9.000	11394.555	657.378	0.931	1.115	580.645	COMPACT	
37	29.000	28.000	22.000	3.500	9353.566	637.743	0.842	1.295	241.379	COMPACT	
38	34.000	26.000	23.000	7.000	10645.809	694.292	0.843	1.304	411.765	COMPACT	ELONGATED
39	36.000	34.000	26.000	7.500	16663.004	961.327	0.820	1.346	416.667	COMPACT	
40	32.000	26.000	25.000	9.500	10890.852	653.451	0.909	1.160	593.750	COMPACT	
41	37.000	31.000	29.000	6.500	17416.465	900.852	0.902	1.172	351.351	COMPACT	
42	35.000	30.000	20.000	4.500	10995.574	824.668	0.725	1.625	257.143	COMPACT	BLADED
43	23.000	22.000	21.000	8.500	5563.758	397.411	0.955	1.071	739.130	COMPACT	
44	30.000	29.000	28.000	9.000	12754.863	683.296	0.966	1.054	600.000	COMPACT	
45	23.000	22.000	21.000	5.500	5563.758	397.411	0.955	1.071	478.261	COMPACT	
46	29.000	28.000	27.000	6.500	11479.379	637.743	0.965	1.056	448.276	COMPACT	
47	29.000	27.000	25.000	9.000	10249.445	614.967	0.928	1.120	620.689	COMPACT	
48	30.000	28.000	22.000	7.000	9676.102	659.734	0.832	1.318	466.667	COMPACT	
49	29.000	26.000	25.000	6.000	9869.836	592.190	0.939	1.100	413.793	COMPACT	
50	32.000	27.000	25.000	5.500	11309.730	678.584	0.898	1.180	343.750	COMPACT	
51	47.000	30.000	28.000	4.000	20671.676	1107.411	0.822	1.375	170.213	COMPACT	ELONGATED
52	81.000	60.000	16.000	7.000	40715.039	3817.035	0.375	4.406	172.839	VERY	PLATY
53	68.000	40.000	34.000	8.000	48422.414	2136.283	0.752	1.588	235.294		ELONGATED
54	41.000	21.000	12.000	5.000	5409.820	676.228	0.551	2.583	243.902	VERY	ELONGATED
55	67.000	42.000	19.000	6.000	27994.730	2210.110	0.504	2.868	179.104	VERY	BLADED
56	55.000	29.000	19.000	9.500	15867.660	1252.710	0.609	2.211	345.454		ELONGATED
57	80.000	35.000	16.000	4.000	23457.223	2199.115	0.450	3.594	100.000	VERY	ELONGATED
58	52.000	23.000	13.000	5.000	8140.910	939.336	0.521	2.885	192.308	VERY	ELONGATED
59	47.000	45.000	24.000	6.000	26577.871	1661.117	0.648	1.917	255.319	COMPACT	PLATY
60	70.000	60.000	20.000	9.000	43982.297	3298.672	0.457	3.250	257.143	VERY	PLATY
61	50.000	30.000	18.000	4.000	14137.164	1178.097	0.600	2.222	160.000		BLADED
62	50.000	38.000	15.000	5.000	14922.563	1492.256	0.491	2.933	200.000	VERY	BLADED
63	58.000	38.000	18.000	5.000	20772.207	1731.017	0.528	2.667	172.414	VERY	BLADED
64	65.000	45.000	21.000	6.000	32162.055	2297.290	0.532	2.619	184.615	VERY	BLADED
65	54.000	30.000	27.000	5.000	22902.207	1272.345	0.766	1.556	185.185		ELONGATED
66	80.000	40.000	13.000	4.000	21781.707	2513.274	0.375	4.615	100.000	VERY	BLADED
67	52.000	43.000	29.000	8.000	33952.238	1756.150	0.722	1.638	307.692	COMPACT	BLADED
68	63.000	58.000	18.000	9.500	34438.137	2869.845	0.445	3.361	301.587	VERY	PLATY
69	74.000	52.000	32.000	6.500	64473.855	3022.212	0.643	1.969	175.676		BLADED
70	70.000	45.000	30.000	7.000	49480.082	2474.004	0.659	1.917	200.000		BLADED
71	61.000	41.000	10.000	6.000	13095.203	1964.281	0.342	5.100	196.721	VERY	BLADED
72	51.000	32.000	21.000	8.000	17944.773	1281.770	0.647	1.976	313.725		BLADED
73	64.000	48.000	18.000	5.000	28952.914	2412.743	0.472	3.111	156.250	VERY	BLADED
74	54.000	48.000	13.000	5.000	17643.184	2035.752	0.402	3.923	185.185	VERY	PLATY
75	50.000	32.000	14.000	4.000	11728.609	1256.637	0.497	2.929	160.000	VERY	BLADED
76	43.000	37.000	21.000	4.500	17493.957	1249.568	0.652	1.905	209.302		PLATY
77	42.000	38.000	10.000	4.000	8356.633	1253.495	0.397	4.000	190.476	VERY	PLATY
78	55.000	35.000	15.000	4.000	15118.914	1511.891	0.489	3.000	145.455	VERY	BLADED
79	50.000	32.000	17.000	5.000	14241.883	1256.637	0.565	2.412	200.000		BLADED
80	64.000	35.000	25.000	7.000	29321.531	1759.292	0.653	1.980	218.750		ELONGATED
81	47.000	35.000	17.000	7.000	14642.438	1291.980	0.560	2.412	297.872		BLADED
82	58.000	32.000	11.000	3.000	10689.789	1457.699	0.402	4.091	103.448	VERY	BLADED
83	62.000	35.000	29.000	6.000	32950.070	1704.314	0.729	1.672	193.548		ELONGATED
84	50.000	40.000	28.000	3.800	29321.531	1570.796	0.732	1.607	152.000	COMPACT	BLADED
85	67.000	45.000	32.000	8.000	50516.809	2367.975	0.698	1.750	238.806		BLADED
86	60.000	35.000	24.000	8.000	26389.375	1649.336	0.650	1.979	266.667		ELONGATED
87	42.000	22.000	18.000	5.500	8708.492	725.708	0.705	1.778	261.905		ELONGATED
88	45.000	20.000	12.000	4.500	5654.863	706.858	0.543	2.708	200.000	VERY	ELONGATED
89	58.000	45.000	24.000	5.000	32798.227	2049.889	0.604	2.146	172.414		BLADED
90	40.000	30.000	23.000	5.500	14451.324	942.478	0.761	1.522	275.000	COMPACT	BLADED
91	57.000	40.000	36.000	7.500	42976.984	1790.708	0.828	1.347	263.156	COMPACT	ELONGATED
92	64.000	43.000	17.000	5.000	24496.043	2161.415	0.472	3.147	156.250	VERY	BLADED
93	42.000	39.000	18.000	6.000	15437.785	1286.482	0.583	2.250	285.714		PLATY
94	55.000	41.000	26.000	7.000	30698.594	1771.073	0.669	1.846	254.545		BLADED
95	52.000	30.000	18.000	5.000	14702.652	1225.221	0.592	2.278	192.308		BLADED
96	54.000	29.000	16.000	5.000	13119.289	1229.933	0.547	2.594	185.185	VERY	BLADED
97	68.000	47.000	17.000	5.500	28448.168	2510.132	0.443	3.382	161.765	VERY	BLADED
98	62.000	32.000	22.000	6.000	22854.039	1558.230	0.625	2.136	193.548		ELONGATED
99	42.000	35.000	18.000	8.500	13854.422	1154.535	0.604	2.139	404.762		PLATY
100	66.000	38.000	19.000	5.000	24950.527	1969.779	0.524	2.737	151.515	VERY	BLADED

Table 20 Shape measurements of pebbles

(II-22)

PEDIMENT 3 SITE ONE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	85.000	75.000	50.000	8.500	166897.063	5006.910	0.732	1.600	200.000	COMPACT	PLATY
2	99.000	72.000	53.000	8.000	197807.188	5598.316	0.733	1.613	161.616	COMPACT	BLADED
3	90.000	70.000	50.000	9.000	164933.563	4948.008	0.735	1.600	200.000	COMPACT	BLADED
4	94.000	80.000	50.000	5.500	196873.125	5906.191	0.693	1.740	117.021	COMPACT	PLATY
5	96.000	94.000	53.000	8.500	250422.625	7087.430	0.678	1.792	177.083	COMPACT	PLATY
6	93.000	85.000	72.000	8.000	298011.438	6208.570	0.869	1.236	172.043	COMPACT	
7	98.000	76.000	55.000	6.500	214487.000	5849.645	0.741	1.582	132.653	COMPACT	BLADED
8	90.000	70.000	52.000	6.000	171530.938	4948.008	0.754	1.538	133.333	COMPACT	BLADED
9	81.000	65.000	55.000	7.500	151621.063	4135.121	0.831	1.327	185.185	COMPACT	BLADED
10	96.000	85.000	70.000	7.000	299079.563	6408.848	0.844	1.293	145.833	COMPACT	
11	93.000	73.000	60.000	7.000	213282.688	5332.066	0.809	1.383	150.538	COMPACT	BLADED
12	86.000	74.000	60.000	5.500	199930.938	4998.273	0.827	1.333	127.907	COMPACT	BLADED
13	89.000	75.000	67.000	8.500	234166.438	5242.531	0.876	1.224	191.011	COMPACT	
14	80.000	63.000	61.000	7.000	160975.188	3958.407	0.904	1.172	175.000	COMPACT	
15	90.000	80.000	73.000	8.000	275203.500	5654.863	0.905	1.164	177.778	COMPACT	
16	60.000	50.000	30.000	5.000	47123.887	2356.194	0.669	1.833	166.667		BLADED
17	65.000	60.000	59.000	9.000	120480.063	3063.053	0.963	1.059	276.923	COMPACT	
18	45.000	41.000	34.000	7.500	32845.348	1449.060	0.856	1.265	333.333	COMPACT	
19	50.000	40.000	20.000	5.000	20943.949	1570.796	0.585	2.250	200.000		BLADED
20	72.000	65.000	35.000	5.000	85765.438	3675.663	0.640	1.957	138.889		PLATY
21	59.000	53.000	39.000	3.500	63854.441	2455.940	0.786	1.436	118.644	COMPACT	PLATY
22	55.000	50.000	49.000	6.000	70554.875	2159.845	0.956	1.071	218.182	COMPACT	
23	99.000	83.000	53.000	9.500	228027.750	6453.613	0.699	1.717	191.919	COMPACT	BLADED
24	95.000	83.000	58.000	7.000	239457.375	6192.863	0.753	1.534	147.368	COMPACT	PLATY
25	95.000	76.000	55.000	9.500	207921.063	5670.574	0.748	1.555	200.000	COMPACT	BLADED
26	53.000	35.000	34.000	6.500	33023.371	1456.914	0.854	1.294	245.283	COMPACT	ELONGATED
27	58.000	55.000	46.000	7.000	76832.875	2505.420	0.872	1.228	241.379	COMPACT	
28	51.000	46.000	29.000	4.500	35622.516	1842.544	0.710	1.672	176.471	COMPACT	PLATY
29	63.000	46.000	39.000	5.500	59178.180	2276.084	0.807	1.397	174.603	COMPACT	ELONGATED
30	57.000	56.000	55.000	5.500	91923.000	2506.991	0.982	1.027	192.982	COMPACT	
31	62.000	60.000	59.000	5.000	114919.438	2921.681	0.978	1.034	161.290	COMPACT	
32	47.000	45.000	41.000	9.500	45403.867	1661.117	0.926	1.122	404.255	COMPACT	
33	51.000	41.000	21.000	5.000	22991.742	1642.267	0.595	2.190	196.078		BLADED
34	56.000	49.000	34.000	6.000	48849.668	2155.132	0.750	1.544	214.286	COMPACT	PLATY
35	65.000	45.000	41.000	7.800	62792.582	2297.290	0.831	1.341	240.000	COMPACT	ELONGATED
36	60.000	50.000	40.000	4.500	62831.852	2356.194	0.811	1.375	150.000	COMPACT	BLADED
37	46.000	45.000	34.000	7.500	36850.879	1625.774	0.823	1.338	326.087	COMPACT	
38	68.000	62.000	30.000	5.000	66224.750	3311.239	0.598	2.167	147.059		PLATY
39	47.000	42.000	35.000	6.000	36175.438	1550.376	0.853	1.271	255.319	COMPACT	
40	50.000	45.000	25.000	4.000	29452.430	1767.146	0.652	1.900	160.000		PLATY
41	81.000	57.000	50.000	6.000	120872.750	3626.183	0.815	1.380	148.148	COMPACT	ELONGATED
42	61.000	50.000	30.000	4.000	47909.285	2395.464	0.666	1.850	131.148		BLADED
43	75.000	70.000	32.000	5.000	87964.563	4123.340	0.580	2.266	133.333		PLATY
44	78.000	75.000	33.000	3.500	101080.688	4594.578	0.571	2.318	89.744		PLATY
45	46.000	37.000	32.000	7.000	28517.281	1336.748	0.844	1.297	304.348	COMPACT	BLADED
46	50.000	48.000	40.000	8.500	50265.480	1884.956	0.874	1.225	340.000	COMPACT	
47	59.000	46.000	35.000	5.000	49736.645	2131.571	0.767	1.500	169.492	COMPACT	BLADED
48	62.000	44.000	35.000	5.000	49993.211	2142.566	0.766	1.514	161.290	COMPACT	ELONGATED
49	60.000	50.000	45.000	7.500	70685.813	2356.194	0.877	1.222	250.000	COMPACT	
50	47.000	35.000	30.000	8.500	25839.598	1291.980	0.818	1.367	361.702	COMPACT	ELONGATED
51	58.000	26.000	16.000	5.000	12633.391	1184.380	0.554	2.625	172.414	VERY	ELONGATED
52	57.000	29.000	30.000	3.000	25965.262	1298.263	0.817	1.433	105.263	COMPACT	ELONGATED
53	31.000	25.000	14.000	6.000	5681.043	608.683	0.632	2.000	387.097		BLADED
54	36.000	22.000	17.000	3.000	7049.730	622.035	0.715	1.706	166.667		ELONGATED
55	36.000	25.000	16.000	4.000	7539.820	706.858	0.658	1.906	222.222		BLADED
56	37.000	19.000	16.000	4.000	5889.438	552.135	0.714	1.750	216.216		ELONGATED
57	29.000	12.000	10.000	4.000	1822.124	273.318	0.660	2.050	275.862		ELONGATED
58	53.000	27.000	14.000	5.000	10489.777	1123.905	0.515	2.857	188.679	VERY	ELONGATED
59	36.000	26.000	19.000	3.500	9311.680	735.133	0.728	1.632	194.444	COMPACT	BLADED
60	50.000	30.000	20.000	5.000	15707.961	1178.097	0.644	2.000	200.000		ELONGATED
61	40.000	36.000	19.000	6.500	14325.660	1130.973	0.631	2.000	325.000		PLATY
62	47.000	28.000	14.000	4.500	9646.781	1033.584	0.530	2.679	191.489	VERY	BLADED
63	40.000	23.000	15.000	5.500	7225.660	722.566	0.625	2.100	275.000		ELONGATED
64	42.000	32.000	28.000	4.000	19704.066	1055.575	0.836	1.321	190.476	COMPACT	ELONGATED
65	46.000	22.000	15.000	3.000	7948.227	794.823	0.606	2.267	130.435	VERY	ELONGATED
66	46.000	33.000	14.000	3.500	11127.520	1192.234	0.505	2.821	152.174	VERY	BLADED
67	32.000	22.000	11.000	5.000	4054.749	552.920	0.556	2.455	312.500		BLADED
68	42.000	32.000	20.000	5.000	14074.332	1055.575	0.668	1.850	238.095		BLADED
69	44.000	24.000	19.000	4.500	10505.484	829.380	0.699	1.789	204.545		ELONGATED
70	41.000	20.000	17.000	4.500	7298.965	644.026	0.706	1.794	219.512		ELONGATED
71	41.000	20.000	12.000	5.000	5152.211	644.026	0.560	2.542	243.902	VERY	ELONGATED
72	39.000	21.000	12.000	5.000	5145.926	643.241	0.560	2.500	256.410	VERY	ELONGATED
73	39.000	29.000	14.000	4.000	8290.660	888.285	0.558	2.429	205.128		BLADED
74	37.000	27.000	10.000	3.000	5230.750	784.613	0.464	3.200	162.162	VERY	BLADED
75	36.000	31.000	10.000	6.000	5843.359	876.504	0.447	3.350	333.333	VERY	PLATY
76	50.000	25.000	10.000	4.000	6544.984	981.748	0.431	3.750	160.000	VERY	BLADED
77	42.000	34.000	16.000	3.000	11963.184	1121.548	0.564	2.375	142.857		PLATY
78	39.000	19.000	16.000	3.000	6207.785	581.980	0.702	1.813	153.846		ELONGATED
79	40.000	30.000	11.000	3.500	6911.500	942.478	0.465	3.182	175.000	VERY	BLADED
80	39.000	29.000	13.000	5.000	7698.473	888.285	0.531	2.615	256.410	VERY	BLADED
81	42.000	32.000	14.000	7.000	9852.031	1055.575	0.526	2.643	333.333	VERY	BLADED
82	40.000	34.000	11.000	4.500	7833.035	1068.141	0.446	3.364	225.000	VERY	PLATY
83	57.000	34.000	20.000	6.000	20294.688	1522.102	0.591	2.275	210.526		BLADED
84	32.000	23.000	15.000	3.500	5780.527	578.053	0.674	1.833	218.750		BLADED
85	38.000	28.000	18.000	4.000	10027.961	835.664	0.673	1.833	210.526		BLADED
86	30.000	22.000	15.000	6.000	5183.625	518.363	0.699	1.733	400.000		BLADED
87	45.000	34.000	22.000	8.000	17624.332	1201.659	0.681	1.795	355.555		BLADED
88	36.000	21.000	10.000	5.000	3958.407	593.761	0.510	2.850	277.778	VERY	BLADED
89	37.000	27.000	15.000	4.000	7846.125	784.613	0.608	2.133	216.216		BLADED
90	30.000	22.000	11.000	4.500	3801.327	518.363	0.568	2.364	300.000		BLADED
91	32.000	23.000	20.000	4.000	7707.371	578.053	0.816	1.375	250.000	COMPACT	ELONGATED
92	73.000	35.000	26.000	6.500	34782.664	2006.692	0.642	2.077	178.082		ELONGATED
93	43.000	31.000	13.000	6.000	9073.441	1046.936	0.502	2.846	279.070	VERY	BLADED
94	35.000	21.000	15.000	3.500	5772.676	577.268	0.674	1.867	200.000		ELONGATED
95	65.000	49.000	36.000	5.500	60035.832	2501.493	0.741	1.583	169.231	COMPACT	BLADED
96	57.000	27.000	17.000	5.000	13698.914	1208.728	0.573	2.471	175.439	VERY	ELONGATED
97	37.000	20.000	18.000	5.000	6974.332	581.195	0.759	1.583	270.270		ELONGATED
98	36.000	21.000	15.000	4.000	5937.609	593.761	0.668	1.900	222.222		ELONGATED
99	55.000	41.000	18.000	7.000	21252.871	1771.073	0.524	2.667	254.545	VERY	BLADED
100	82.000	65.000	32.000	8.000	89305.000	4186.172	0.577	2.297	195.122		BLADED

Table 21 Shape measurements of pebbles

PEDIMENT B SITE TWO

(II-23)

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	66.000	60.000	40.000	4.500	82938.000	3110.177	0.739	1.575	136.364	COMPACT	PLATY
2	45.000	40.000	30.000	9.500	28274.332	1413.717	0.794	1.417	422.222	COMPACT	BLADED
3	50.000	47.000	42.000	8.500	51679.195	1845.686	0.909	1.155	340.000	COMPACT	
4	65.000	55.000	40.000	5.000	74874.563	2807.798	0.765	1.500	153.846	COMPACT	BLADED
5	56.000	40.000	35.000	5.500	41050.141	1759.292	0.818	1.371	196.429	COMPACT	ELONGATED
6	47.000	37.000	32.000	6.500	29137.223	1365.807	0.838	1.313	276.596	COMPACT	ELONGATED
7	60.000	54.000	30.000	5.000	50893.801	2544.690	0.652	1.900	166.667		PLATY
8	97.000	87.000	57.000	3.500	251863.000	6627.973	0.727	1.614	72.165	COMPACT	PLATY
9	52.000	40.000	28.000	6.500	30494.391	1633.628	0.722	1.643	250.000	COMPACT	BLADED
10	50.000	40.000	37.000	6.500	38746.309	1570.796	0.881	1.216	260.000	COMPACT	
11	50.000	45.000	30.000	9.000	35342.914	1767.146	0.737	1.583	360.000	COMPACT	PLATY
12	40.000	30.000	20.000	6.000	12566.367	942.478	0.693	1.750	300.000		BLADED
13	41.000	38.000	35.000	6.500	28551.840	1223.650	0.923	1.129	317.073	COMPACT	
14	45.000	40.000	32.000	3.500	30159.289	1413.717	0.829	1.328	155.556	COMPACT	
15	44.000	36.000	32.000	6.500	26540.172	1244.071	0.865	1.250	295.454	COMPACT	
16	56.000	55.000	45.000	3.000	72570.750	2419.026	0.870	1.233	107.143	COMPACT	
17	56.000	43.000	41.000	4.000	51693.859	1891.239	0.887	1.207	142.857	COMPACT	
18	42.000	35.000	25.000	5.500	19242.254	1154.535	0.752	1.540	261.905	COMPACT	BLADED
19	65.000	55.000	40.000	2.500	74874.563	2807.798	0.765	1.500	76.923	COMPACT	BLADED
20	50.000	48.000	27.000	7.500	33929.199	1884.956	0.672	1.815	300.000	COMPACT	PLATY
21	46.000	37.000	30.000	6.500	26734.953	1336.748	0.809	1.383	282.609	COMPACT	BLADED
22	39.000	37.000	30.000	9.500	22666.590	1133.329	0.854	1.267	487.179	COMPACT	
23	50.000	45.000	35.000	6.000	41233.402	1767.146	0.817	1.357	240.000	COMPACT	
24	50.000	40.000	28.000	5.000	29321.531	1570.796	0.732	1.607	200.000	COMPACT	BLADED
25	50.000	40.000	30.000	9.500	31415.926	1570.796	0.766	1.500	380.000	COMPACT	BLADED
26	58.000	49.000	39.000	6.500	58034.641	2232.102	0.812	1.372	224.138	COMPACT	BLADED
27	47.000	45.000	30.000	5.000	33222.340	1661.117	0.752	1.533	212.766	COMPACT	PLATY
28	43.000	42.000	14.000	2.500	13238.668	1418.429	0.477	3.036	116.279	VERY	PLATY
29	46.000	29.000	20.000	3.000	13969.613	1047.721	0.669	1.875	130.435		BLADED
30	45.000	43.000	30.000	3.500	30394.906	1519.745	0.775	1.467	155.556	COMPACT	PLATY
31	45.000	41.000	27.000	3.500	26083.070	1449.060	0.734	1.593	155.556	COMPACT	PLATY
32	49.000	44.000	32.000	5.500	36124.125	1693.318	0.780	1.453	224.490	COMPACT	PLATY
33	60.000	50.000	26.000	2.000	40840.703	2356.194	0.609	2.115	66.667		PLATY
34	50.000	40.000	35.000	9.000	36651.914	1570.796	0.849	1.286	360.000	COMPACT	
35	65.000	50.000	42.000	4.000	71471.188	2552.544	0.816	1.369	123.077	COMPACT	BLADED
36	55.000	50.000	35.000	5.500	50396.379	2159.845	0.764	1.500	200.000	COMPACT	PLATY
37	47.000	45.000	26.000	3.500	28792.695	1661.117	0.684	1.769	148.936	COMPACT	PLATY
38	50.000	40.000	35.000	6.000	36651.914	1570.796	0.849	1.286	240.000	COMPACT	
39	46.000	43.000	24.000	5.000	24856.277	1553.517	0.663	1.854	217.391	COMPACT	PLATY
40	61.000	56.000	20.000	5.500	35772.266	2682.920	0.489	2.925	180.328	VERY	PLATY
41	68.000	65.000	55.000	8.000	127286.813	3471.460	0.881	1.209	235.294	COMPACT	
42	45.000	44.000	20.000	7.000	20734.508	1555.088	0.587	2.225	311.111		PLATY
43	65.000	45.000	40.000	8.500	61261.055	2297.290	0.818	1.375	261.538	COMPACT	ELONGATED
44	50.000	34.000	31.000	7.500	27593.652	1335.177	0.827	1.355	300.000	COMPACT	ELONGATED
45	52.000	50.000	21.000	5.500	28588.492	2042.035	0.554	2.429	211.538		PLATY
46	47.000	45.000	27.000	7.500	29900.105	1661.117	0.701	1.704	319.149	COMPACT	PLATY
47	37.000	35.000	24.000	4.500	16273.449	1017.091	0.763	1.500	243.243	COMPACT	PLATY
48	45.000	40.000	38.000	8.500	35814.156	1413.717	0.929	1.118	377.778	COMPACT	
49	48.000	30.000	27.000	5.400	20357.520	1130.973	0.797	1.444	225.000	COMPACT	ELONGATED
50	50.000	45.000	30.000	3.500	35342.914	1767.146	0.737	1.583	140.000	COMPACT	PLATY
51	60.000	40.000	26.000	7.000	32672.563	1884.956	0.656	1.923	233.333		BLADED
52	62.000	45.000	17.000	8.500	24834.289	2191.261	0.470	3.147	274.193	VERY	BLADED
53	40.000	25.000	18.000	3.000	9424.777	785.398	0.687	1.806	150.000		ELONGATED
54	48.000	35.000	26.000	4.500	22870.793	1319.469	0.738	1.596	187.500	COMPACT	BLADED
55	68.000	30.000	17.000	5.500	18158.402	1602.212	0.521	2.882	161.765	VERY	ELONGATED
56	50.000	37.000	10.000	4.000	9686.574	1452.987	0.378	4.350	160.000	VERY	PLATY
57	50.000	30.000	23.000	8.500	18064.156	1178.097	0.707	1.739	340.000		ELONGATED
58	70.000	50.000	24.000	3.800	43982.297	2748.894	0.548	2.500	108.571		BLADED
59	61.000	45.000	10.000	5.000	14372.785	2155.918	0.332	5.300	163.934	VERY	PLATY
60	78.000	58.000	28.000	8.800	66325.250	3553.141	0.558	2.429	225.641		BLADED
61	54.000	30.000	16.000	3.500	13571.680	1272.345	0.541	2.625	129.630	VERY	BLADED
62	55.000	36.000	19.000	5.000	19697.785	1555.088	0.567	2.395	181.818		BLADED
63	60.000	50.000	18.000	4.500	28274.332	2356.194	0.476	3.056	150.000	VERY	PLATY
64	66.000	45.000	17.000	7.000	26436.500	2332.632	0.460	3.265	212.121	VERY	BLADED
65	70.000	50.000	20.000	6.500	36651.914	2748.894	0.485	3.000	185.714	VERY	BLADED
66	50.000	40.000	16.000	5.500	16755.160	1570.796	0.504	2.813	220.000	VERY	PLATY
67	58.000	46.000	17.000	5.000	23748.344	2095.442	0.477	3.059	172.414	VERY	PLATY
68	66.000	50.000	17.000	6.000	29373.891	2591.814	0.444	3.412	181.818	VERY	PLATY
69	58.000	34.000	24.000	5.500	24780.883	1548.805	0.663	1.917	189.655		ELONGATED
70	54.000	33.000	17.000	4.000	15861.898	1399.579	0.545	2.559	148.148	VERY	BLADED
71	51.000	30.000	14.000	6.000	11215.484	1201.659	0.504	2.893	235.294	VERY	BLADED
72	48.000	30.000	15.000	3.500	11309.730	1130.973	0.539	2.600	145.833	VERY	BLADED
73	57.000	30.000	13.000	4.000	11639.598	1343.031	0.462	3.346	140.351	VERY	BLADED
74	35.000	26.000	13.000	3.000	6194.172	714.712	0.571	2.346	171.429		BLADED
75	50.000	40.000	16.000	5.000	16755.160	1570.796	0.504	2.813	200.000	VERY	PLATY
76	48.000	25.000	10.000	6.000	6283.184	942.478	0.437	3.650	250.000	VERY	BLADED
77	90.000	75.000	32.000	9.500	113097.313	5301.438	0.533	2.578	211.111		PLATY
78	50.000	26.000	15.000	5.000	10210.176	1021.018	0.557	2.533	200.000	VERY	ELONGATED
79	68.000	30.000	15.000	5.000	16022.121	1602.212	0.480	3.267	147.059	VERY	ELONGATED
80	66.000	43.000	15.000	8.500	22289.598	2228.960	0.430	3.633	257.576	VERY	BLADED
81	50.000	27.000	12.000	7.000	8482.297	1060.287	0.474	3.208	280.000	VERY	BLADED
82	60.000	40.000	29.000	9.500	36442.473	1884.956	0.705	1.724	316.667		BLADED
83	40.000	34.000	16.000	4.000	11393.508	1068.141	0.573	2.313	200.000		PLATY
84	54.000	35.000	13.000	6.000	12864.820	1484.402	0.447	3.423	222.222	VERY	BLADED
85	49.000	34.000	13.000	5.500	11340.102	1308.473	0.466	3.192	224.490	VERY	BLADED
86	46.000	38.000	11.000	6.000	10067.754	1372.876	0.411	3.818	260.869	VERY	PLATY
87	45.000	35.000	10.000	5.000	8246.680	1237.002	0.399	4.000	222.222	VERY	PLATY
88	47.000	24.000	12.000	4.000	7087.430	885.929	0.504	2.958	170.213	VERY	BLADED
89	42.000	40.000	23.000	5.000	20231.855	1319.469	0.680	1.783	238.095	COMPACT	PLATY
90	70.000	51.000	22.000	5.500	41123.445	2803.871	0.514	2.750	157.143	VERY	BLADED
91	50.000	41.000	12.000	4.500	12880.527	1610.066	0.413	3.792	180.000	VERY	PLATY
92	47.000	30.000	17.000	5.000	12550.660	1107.411	0.590	2.265	212.766		BLADED
93	61.000	35.000	20.000	5.500	22357.664	1676.825	0.572	2.400	180.328	VERY	BLADED
94	48.000	35.000	11.000	7.000	9676.102	1319.469	0.416	3.773	291.667	VERY	BLADED
95	45.000	31.000	21.000	7.000	15338.824	1095.630	0.681	1.810	311.111		BLADED
96	56.000	38.000	14.000	6.000	15599.055	1671.327	0.452	3.357	214.286	VERY	BLADED
97	68.000	30.000	21.000	5.000	22430.969	1602.212	0.600	2.333	147.059	VERY	ELONGATED
98	37.000	20.000	13.000	3.500	5037.020	581.195	0.611	2.192	189.189		ELONGATED
99	82.000	55.000	26.000	5.500	61397.191	3542.146	0.531	2.635	134.146	VERY	BLADED
100	68.000	50.000	23.000	7.500	40945.422	2670.354	0.538	2.565	220.588		BLADED

Table 22 Shape measurements of pebbles

PLOIMENT B SITE THREE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	57.000	54.000	30.000	5.500	48349.109	2417.455	0.664	1.850	192.982	COMPACT	PLATY
2	85.000	55.000	30.000	8.000	73434.688	3671.736	0.577	2.333	188.235		BLADED
3	55.000	50.000	40.000	7.500	57595.863	2159.845	0.835	1.313	272.727	COMPACT	
4	55.000	50.000	25.000	6.000	35997.414	2159.845	0.610	2.100	218.182		PLATY
5	50.000	40.000	30.000	5.500	31415.926	1570.796	0.766	1.500	220.000	COMPACT	BLADED
6	65.000	45.000	44.000	6.000	67387.125	2297.290	0.871	1.250	184.615	COMPACT	ELONGATED
7	65.000	55.000	35.000	9.500	65515.293	2807.798	0.703	1.714	292.308	COMPACT	BLADED
8	65.000	60.000	40.000	8.000	81681.375	3063.053	0.743	1.563	246.154	COMPACT	PLATY
9	43.000	40.000	30.000	3.500	27017.695	1350.885	0.806	1.383	162.791	COMPACT	PLATY
10	65.000	57.000	27.000	4.000	52378.203	2909.900	0.582	2.259	123.077		PLATY
11	43.000	38.000	32.000	3.500	27377.930	1283.341	0.856	1.266	162.791	COMPACT	
12	51.000	50.000	30.000	2.500	40055.305	2002.765	0.707	1.683	98.039	COMPACT	PLATY
13	53.000	41.000	27.000	9.500	30720.063	1706.670	0.695	1.741	358.490	COMPACT	BLADED
14	50.000	39.000	32.000	8.000	32672.563	1531.526	0.807	1.391	320.000	COMPACT	BLADED
15	62.000	58.000	33.000	7.500	62134.418	2824.292	0.672	1.818	241.935	COMPACT	PLATY
16	49.000	42.000	18.000	9.000	19396.191	1616.349	0.540	2.528	367.347		PLATY
17	45.000	35.000	25.000	7.000	20616.699	1237.002	0.735	1.600	311.111	COMPACT	BLADED
18	50.000	31.000	18.000	4.000	14608.402	1217.367	0.593	2.250	160.000		BLADED
19	45.000	43.000	38.000	8.000	38500.215	1519.745	0.907	1.158	355.555	COMPACT	
20	44.000	42.000	27.000	9.500	26125.484	1451.416	0.733	1.593	431.818	COMPACT	PLATY
21	45.000	43.000	23.000	4.500	23302.762	1519.745	0.649	1.913	200.000	COMPACT	PLATY
22	50.000	38.000	31.000	6.000	30839.965	1492.256	0.797	1.419	240.000	COMPACT	BLADED
23	55.000	43.000	37.000	8.000	45817.508	1857.467	0.833	1.324	290.909	COMPACT	ELONGATED
24	40.000	36.000	19.000	7.000	14325.660	1130.973	0.631	2.000	350.000		PLATY
25	47.000	45.000	25.000	4.000	27685.285	1661.117	0.666	1.840	170.213	COMPACT	PLATY
26	50.000	45.000	30.000	3.500	35342.914	1767.146	0.737	1.583	140.000	COMPACT	PLATY
27	47.000	44.000	42.000	9.000	45477.691	1624.203	0.948	1.083	382.979	COMPACT	
28	65.000	50.000	27.000	7.500	45945.789	2552.544	0.608	2.130	230.769		BLADED
29	50.000	38.000	31.000	6.000	30839.965	1492.256	0.797	1.419	240.000	COMPACT	BLADED
30	41.000	39.000	20.000	5.500	16744.688	1255.852	0.630	2.000	268.292		PLATY
31	47.000	40.000	28.000	6.000	27562.238	1476.548	0.747	1.554	255.319	COMPACT	BLADED
32	49.000	47.000	23.000	3.500	27734.500	1808.772	0.612	2.087	142.857		PLATY
33	46.000	43.000	40.000	8.000	41427.133	1553.517	0.932	1.112	347.826	COMPACT	
34	55.000	40.000	25.000	6.500	28797.930	1727.876	0.657	1.900	236.364		BLADED
35	89.000	72.000	56.000	8.000	187892.313	5032.828	0.788	1.438	179.775	COMPACT	BLADED
36	45.000	40.000	35.000	8.500	32986.723	1413.717	0.880	1.214	377.778	COMPACT	
37	45.000	35.000	30.000	9.000	24740.039	1237.002	0.830	1.333	400.000	COMPACT	ELONGATED
38	45.000	35.000	30.000	9.000	24740.039	1237.002	0.830	1.333	400.000	COMPACT	ELONGATED
39	45.000	40.000	35.000	8.500	32986.723	1413.717	0.880	1.214	377.778	COMPACT	
40	70.000	69.000	30.000	5.500	75869.438	3793.473	0.571	2.317	157.143		PLATY
41	90.000	82.000	71.000	9.500	274355.250	5796.238	0.881	1.211	211.111	COMPACT	
42	90.000	89.000	50.000	9.500	209701.250	6291.039	0.678	1.790	211.111	COMPACT	PLATY
43	85.000	80.000	30.000	9.000	106814.125	5340.707	0.510	2.750	211.765		PLATY
44	98.000	85.000	67.000	9.000	292225.688	6542.363	0.814	1.366	183.673	COMPACT	BLADED
45	29.000	20.000	19.000	9.500	5770.055	455.531	0.854	1.289	655.172	COMPACT	ELONGATED
46	25.000	22.000	20.000	8.500	5759.586	431.969	0.899	1.175	680.000	COMPACT	
47	30.000	27.000	25.000	7.500	10602.875	636.172	0.917	1.140	500.000	COMPACT	
48	29.000	28.000	27.000	8.500	11479.379	637.743	0.965	1.056	586.207	COMPACT	
49	80.000	65.000	55.000	9.500	149749.188	4084.070	0.835	1.318	237.500	COMPACT	BLADED
50	42.000	26.000	21.000	5.000	12007.164	857.655	0.739	1.619	238.095		ELONGATED
51	73.000	35.000	25.000	7.000	33444.871	2006.692	0.625	2.160	191.781		ELONGATED
52	57.000	47.000	40.000	4.000	56108.844	2104.082	0.842	1.300	140.351	COMPACT	
53	59.000	45.000	15.000	6.000	20852.320	2085.232	0.439	3.467	203.390	VERY	PLATY
54	37.000	29.000	19.000	5.000	10674.605	842.732	0.696	1.737	270.270	COMPACT	BLADED
55	40.000	27.000	23.000	3.500	13006.191	848.230	0.788	1.457	175.000	COMPACT	ELONGATED
56	46.000	24.000	14.000	4.500	8092.742	867.079	0.562	2.500	195.652	VERY	ELONGATED
57	35.000	24.000	14.000	4.000	6157.520	659.734	0.616	2.107	228.571		BLADED
58	59.000	24.000	15.000	8.000	11121.234	1112.124	0.542	2.767	271.186	VERY	ELONGATED
59	53.000	31.000	18.000	5.000	15484.910	1290.409	0.582	2.333	188.679		BLADED
60	35.000	25.000	11.000	4.500	5039.637	687.223	0.517	2.727	257.143	VERY	BLADED
61	44.000	22.000	21.000	4.500	10643.715	760.265	0.769	1.571	204.545		ELONGATED
62	35.000	29.000	23.000	6.000	12223.410	797.179	0.805	1.391	342.857	COMPACT	BLADED
63	50.000	31.000	11.000	7.000	8927.355	1217.367	0.427	3.682	280.000	VERY	BLADED
64	46.000	36.000	18.000	5.000	15607.430	1300.619	0.581	2.278	217.391		BLADED
65	47.000	33.000	25.000	7.500	20302.539	1218.152	0.739	1.600	319.149	COMPACT	BLADED
66	36.000	31.000	25.000	7.500	14608.402	876.504	0.824	1.340	416.667	COMPACT	BLADED
67	50.000	35.000	16.000	9.000	14660.766	1374.447	0.527	2.656	360.000	VERY	BLADED
68	37.000	31.000	12.000	5.000	7206.813	900.852	0.501	2.833	270.270	VERY	PLATY
69	45.000	39.000	13.000	8.000	11945.902	1378.374	0.458	3.231	355.555	VERY	PLATY
70	52.000	42.000	34.000	8.000	38880.348	1715.310	0.809	1.382	307.692	COMPACT	BLADED
71	57.000	40.000	36.000	5.000	42976.984	1790.708	0.828	1.347	175.439	COMPACT	ELONGATED
72	50.000	28.000	19.000	3.500	13927.727	1099.557	0.636	2.053	140.000		ELONGATED
73	47.000	34.000	17.000	5.500	14224.082	1255.066	0.566	2.382	234.043		BLADED
74	34.000	30.000	12.000	7.000	6408.848	801.106	0.521	2.667	411.765		PLATY
75	35.000	27.000	16.000	5.500	7916.813	742.201	0.647	1.938	314.286		BLADED
76	58.000	35.000	21.000	4.000	22321.016	1594.358	0.601	2.214	137.931		BLADED
77	32.000	30.000	17.000	4.500	8545.129	753.982	0.670	1.824	281.250	COMPACT	PLATY
78	74.000	42.000	12.000	5.500	19528.137	2441.017	0.359	4.833	148.649	VERY	BLADED
79	61.000	37.000	29.000	8.000	34271.109	1772.644	0.720	1.690	262.295		ELONGATED
80	40.000	37.000	26.000	8.000	20148.078	1162.389	0.770	1.481	400.000	COMPACT	PLATY
81	35.000	23.000	21.000	7.000	8851.434	632.245	0.818	1.381	400.000	COMPACT	ELONGATED
82	50.000	26.000	20.000	5.000	13613.566	1021.018	0.675	1.900	200.000		ELONGATED
83	35.000	31.000	14.000	5.500	7953.465	852.157	0.565	2.357	314.286		PLATY
84	50.000	26.000	19.000	5.500	12932.887	1021.018	0.652	2.000	220.000		ELONGATED
85	36.000	27.000	17.000	4.500	8651.945	763.407	0.667	1.853	250.000		BLADED
86	86.000	64.000	18.000	7.000	51873.977	4322.828	0.389	4.167	162.791	VERY	PLATY
87	39.000	25.000	12.000	4.000	6126.105	765.763	0.529	2.667	205.128	VERY	BLADED
88	49.000	36.000	18.000	4.500	16625.305	1385.442	0.568	2.361	183.673		BLADED
89	75.000	59.000	20.000	8.000	46338.488	3475.387	0.449	3.350	213.333	VERY	PLATY
90	35.000	30.000	10.000	3.000	5497.785	824.668	0.457	3.250	171.429	VERY	PLATY
91	42.000	27.000	14.000	5.000	8312.652	890.641	0.557	2.464	238.095	VERY	BLADED
92	45.000	24.000	10.000	4.500	5654.863	848.230	0.452	3.450	200.000	VERY	BLADED
93	48.000	29.000	15.000	3.500	10932.742	1093.274	0.545	2.567	145.833	VERY	BLADED
94	62.000	42.000	15.000	4.500	20451.766	2045.177	0.442	3.467	145.161	VERY	BLADED
95	64.000	50.000	17.000	9.500	28483.770	2513.274	0.449	3.353	296.875	VERY	PLATY
96	47.000	31.000	11.000	6.000	8391.715	1144.325	0.436	3.545	255.319	VERY	BLADED
97	32.000	21.000	16.000	2.000	5629.730	527.787	0.725	1.656	125.000		ELONGATED
98	52.000	25.000	24.000	8.000	16336.281	1021.018	0.762	1.604	307.692		ELONGATED
99	38.000	24.000	13.000	5.000	6207.785	716.283	0.570	2.385	263.158		BLADED
100	38.000	24.000	13.000	5.000	6207.785	716.283	0.570	2.385	263.158		BLADED

Table 23 Shape measurements of pebbles

(II-25)

PEDIMENT 3 SITE FOUR

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	45.000	42.000	17.000	2.500	16823.227	1484.402	0.535	2.559	111.111		PLATY
2	50.000	40.000	30.000	3.500	31415.926	1570.796	0.765	1.500	140.000	COMPACT	BLADED
3	85.000	50.000	40.000	9.500	89011.750	3337.942	0.722	1.688	223.529		ELONGATED
4	60.000	50.000	40.000	6.500	62831.852	2356.194	0.811	1.375	216.667	COMPACT	BLADED
5	50.000	40.000	25.000	5.500	26179.938	1570.796	0.679	1.800	220.000		BLADED
6	50.000	42.000	20.000	4.000	21991.148	1649.336	0.575	2.300	160.000		PLATY
7	70.000	65.000	25.000	9.000	59559.359	3573.562	0.516	2.700	257.143		PLATY
8	66.000	64.000	36.000	8.500	79620.500	3317.522	0.674	1.806	257.576	COMPACT	PLATY
9	90.000	70.000	55.000	9.800	181426.938	4948.008	0.783	1.455	217.778	COMPACT	BLADED
10	35.000	30.000	29.000	4.000	15943.582	824.668	0.929	1.121	228.571	COMPACT	
11	25.000	23.000	19.000	5.500	5720.316	451.604	0.856	1.263	440.000	COMPACT	
12	30.000	27.000	23.000	3.500	9754.645	636.172	0.868	1.239	233.333	COMPACT	
13	43.000	36.000	31.000	2.000	25126.457	1215.796	0.853	1.274	93.023	COMPACT	
14	30.000	26.000	14.000	9.500	5717.695	612.610	0.631	2.000	633.333		PLATY
15	27.000	24.000	21.000	8.000	7125.129	508.938	0.880	1.214	592.593	COMPACT	
16	30.000	25.000	21.000	7.000	8246.680	589.049	0.838	1.310	466.667	COMPACT	
17	33.000	25.000	22.000	4.500	9503.316	647.953	0.837	1.318	272.727	COMPACT	ELONGATED
18	35.000	30.000	24.000	6.000	13194.688	824.668	0.819	1.354	342.857	COMPACT	BLADED
19	32.000	26.000	22.000	6.500	9583.949	653.451	0.835	1.318	406.250	COMPACT	BLADED
20	32.000	29.000	23.000	7.000	11175.691	728.849	0.829	1.326	437.500	COMPACT	
21	40.000	31.000	27.000	6.000	17530.086	973.894	0.838	1.315	300.000	COMPACT	ELONGATED
22	40.000	34.000	31.000	9.500	22074.922	1068.141	0.891	1.194	475.000	COMPACT	
23	42.000	37.000	19.000	2.000	15459.777	1220.509	0.615	2.079	95.238		PLATY
24	35.000	31.000	15.000	3.500	8521.566	852.157	0.592	2.200	200.000		PLATY
25	26.000	25.000	23.000	9.500	7827.801	510.509	0.934	1.109	730.769	COMPACT	
26	27.000	26.000	25.000	8.000	9189.156	551.349	0.962	1.060	592.593	COMPACT	
27	30.000	29.000	26.000	7.500	11843.801	683.296	0.919	1.135	500.000	COMPACT	
28	35.000	31.000	15.000	3.500	8521.566	852.157	0.592	2.200	200.000		PLATY
29	35.000	31.000	27.000	4.000	15338.824	852.157	0.876	1.222	228.571	COMPACT	
30	36.000	34.000	23.000	3.000	14740.352	961.327	0.756	1.522	166.667	COMPACT	PLATY
31	40.000	38.000	15.000	2.500	11938.051	1193.805	0.529	2.600	125.000		PLATY
32	42.000	38.000	28.000	9.500	23398.582	1253.495	0.789	1.429	452.381	COMPACT	PLATY
33	42.000	35.000	27.000	3.000	20781.633	1154.535	0.792	1.426	142.857	COMPACT	BLADED
34	37.000	35.000	17.000	8.500	11527.023	1017.091	0.607	2.118	459.459		PLATY
35	37.000	32.000	27.000	2.500	16738.402	929.911	0.851	1.278	135.135	COMPACT	
36	28.000	26.000	23.000	6.000	8767.137	571.770	0.899	1.174	428.571	COMPACT	
37	30.000	29.000	28.000	5.000	12754.863	683.296	0.966	1.054	333.333	COMPACT	
38	30.000	26.000	21.000	4.500	8576.547	612.610	0.827	1.333	300.000	COMPACT	
39	40.000	33.000	30.000	5.000	20734.508	1036.725	0.880	1.217	250.000	COMPACT	
40	37.000	35.000	25.000	6.500	16951.508	1017.091	0.784	1.440	351.351	COMPACT	PLATY
41	45.000	35.000	25.000	4.500	20616.699	1237.002	0.735	1.600	200.000	COMPACT	BLADED
42	32.000	30.000	25.000	6.500	12566.367	753.982	0.867	1.240	406.250	COMPACT	
43	43.000	40.000	30.000	6.000	27017.695	1350.885	0.806	1.383	279.070	COMPACT	PLATY
44	40.000	27.000	16.000	5.500	9047.785	848.230	0.619	2.094	275.000		BLADED
45	42.000	32.000	30.000	9.000	21111.500	1055.575	0.875	1.233	428.571	COMPACT	
46	30.000	34.000	25.000	3.400	13351.766	801.106	0.849	1.280	226.667	COMPACT	
47	42.000	38.000	30.000	5.500	25069.906	1253.495	0.826	1.333	261.905	COMPACT	
48	30.000	24.000	23.000	7.500	8670.793	565.487	0.902	1.174	500.000	COMPACT	
49	34.000	32.000	14.000	2.500	7975.453	854.513	0.565	2.357	147.059		PLATY
50	40.000	30.000	29.000	9.500	18221.234	942.478	0.888	1.207	475.000	COMPACT	
51	40.000	26.000	25.000	8.000	13613.566	816.814	0.844	1.320	400.000	COMPACT	ELONGATED
52	37.000	29.000	15.000	6.500	8427.320	842.732	0.594	2.200	351.351		BLADED
53	53.000	37.000	18.000	5.000	18481.988	1540.166	0.549	2.500	188.679		BLADED
54	45.000	24.000	23.000	4.500	13006.191	848.230	0.788	1.500	200.000	COMPACT	ELONGATED
55	46.000	18.000	16.000	4.000	6936.633	650.310	0.676	2.000	173.913		ELONGATED
56	49.000	24.000	20.000	6.000	12315.043	923.628	0.698	1.825	244.898		ELONGATED
57	38.000	19.000	15.000	5.500	5670.574	567.057	0.678	1.900	289.474		ELONGATED
58	42.000	25.000	15.000	8.000	8246.680	824.668	0.598	2.233	380.952		BLADED
59	54.000	40.000	17.000	4.000	19226.547	1696.460	0.511	2.765	148.148	VERY	BLADED
60	37.000	20.000	12.000	4.500	4649.555	581.195	0.579	2.375	243.243	VERY	ELONGATED
61	35.000	24.000	23.000	5.000	10115.926	659.734	0.857	1.283	285.714	COMPACT	ELONGATED
62	40.000	27.000	17.000	4.500	9613.273	848.230	0.644	1.971	225.000		BLADED
63	36.000	27.000	15.000	5.500	7634.066	763.407	0.614	2.100	305.555		BLADED
64	49.000	34.000	30.000	4.500	26169.465	1308.473	0.814	1.383	183.673	COMPACT	ELONGATED
65	52.000	39.000	20.000	6.500	21237.164	1592.787	0.582	2.275	250.000		BLADED
66	49.000	26.000	20.000	4.000	13341.293	1000.597	0.680	1.875	163.265		ELONGATED
67	42.000	27.000	16.000	3.500	9500.176	890.641	0.609	2.156	166.667		BLADED
68	41.000	25.000	14.000	2.500	7513.641	805.033	0.576	2.357	121.951		BLADED
69	41.000	40.000	14.000	5.500	12021.824	1288.053	0.493	2.893	268.292		PLATY
70	40.000	25.000	15.000	5.000	7853.980	785.398	0.608	2.167	250.000		BLADED
71	40.000	25.000	15.000	5.000	7853.980	785.398	0.608	2.167	250.000		BLADED
72	55.000	33.000	23.000	5.000	21857.629	1425.498	0.663	1.913	181.818		ELONGATED
73	70.000	33.000	12.000	3.500	14514.156	1814.270	0.397	4.292	100.000	VERY	BLADED
74	67.000	36.000	20.000	3.000	25258.402	1894.380	0.549	2.575	89.552	VERY	BLADED
75	45.000	34.000	29.000	5.000	23232.074	1201.659	0.819	1.362	222.222	COMPACT	ELONGATED
76	44.000	35.000	17.000	3.500	13707.813	1209.513	0.573	2.324	159.091		BLADED
77	41.000	27.000	17.000	3.500	9853.602	869.436	0.639	2.000	170.732		BLADED
78	42.000	33.000	16.000	3.500	11611.324	1088.562	0.569	2.344	166.667		BLADED
79	40.000	25.000	10.000	3.000	5235.984	785.398	0.464	3.250	150.000	VERY	BLADED
80	46.000	26.000	19.000	5.000	11898.258	939.336	0.671	1.895	217.391		ELONGATED
81	41.000	29.000	10.000	5.500	6225.586	933.838	0.438	3.500	268.292	VERY	BLADED
82	77.000	56.000	18.000	5.500	40639.641	3386.637	0.422	3.694	142.857	VERY	BLADED
83	56.000	31.000	15.000	5.500	13634.512	1363.451	0.506	2.900	196.429	VERY	BLADED
84	44.000	29.000	21.000	3.500	14030.352	1002.168	0.702	1.738	159.091		BLADED
85	40.000	33.000	20.000	8.000	13823.004	1036.725	0.672	1.825	400.000		BLADED
86	42.000	23.000	15.000	4.500	7586.945	758.695	0.615	2.167	214.286		ELONGATED
87	93.000	40.000	24.000	5.000	46746.898	2921.681	0.537	2.771	107.527	VERY	ELONGATED
88	42.000	34.000	15.000	5.000	11215.484	1121.548	0.540	2.533	238.095		PLATY
89	50.000	37.000	13.000	3.500	12592.547	1452.987	0.450	3.346	140.000	VERY	BLADED
90	68.000	36.000	17.000	7.000	21790.086	1922.655	0.491	3.059	205.882	VERY	BLADED
91	67.000	33.000	21.000	6.000	24311.211	1736.515	0.584	2.381	179.104	VERY	ELONGATED
92	36.000	27.000	13.000	4.500	6616.191	763.407	0.558	2.423	250.000		BLADED
93	45.000	27.000	18.000	3.500	11451.102	954.259	0.644	2.000	155.556		ELONGATED
94	30.000	22.000	11.000	2.500	3801.327	518.363	0.568	2.364	166.667		BLADED
95	37.000	27.000	11.000	3.500	5753.824	784.613	0.495	2.909	189.189	VERY	BLADED
96	28.000	25.000	18.000	5.000	6597.344	549.779	0.774	1.472	357.143	COMPACT	PLATY
97	60.000	50.000	28.000	6.000	43982.297	2356.194	0.639	1.964	200.000		PLATY
98	56.000	34.000	16.000	4.500	15950.910	1495.398	0.512	2.813	160.714	VERY	BLADED
99	42.000	31.000	24.000	6.000	16361.414	1022.588	0.762	1.521	285.714	COMPACT	BLADED
100	55.000	37.000	17.000	5.000	18113.898	1598.285	0.522	2.706	181.818	VERY	BLADED

Table 24 Shape measurements of pebbles

PEDIMENT B SITE FIVE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	30.000	26.000	19.000	3.500	7759.730	612.610	0.774	1.474	233.333	COMPACT	BLADED
2	40.000	36.000	25.000	6.000	18849.555	1130.973	0.757	1.520	300.000	COMPACT	PLATY
3	43.000	36.000	30.000	7.000	24315.926	1215.796	0.835	1.317	325.581	COMPACT	BLADED
4	37.000	35.000	20.000	3.500	13561.207	1017.091	0.676	1.800	189.189	COMPACT	PLATY
5	30.000	25.000	19.000	5.500	7461.281	589.049	0.784	1.447	366.667	COMPACT	BLADED
6	30.000	23.000	20.000	2.500	7225.660	541.925	0.834	1.325	166.667	COMPACT	ELONGATED
7	35.000	32.000	31.000	8.500	18179.348	879.646	0.950	1.081	485.714	COMPACT	
8	38.000	30.000	26.000	4.500	15519.465	895.354	0.840	1.308	236.842	COMPACT	ELONGATED
9	40.000	37.000	13.000	9.000	10074.039	1162.389	0.485	2.962	450.000	VERY	PLATY
10	36.000	26.000	23.000	7.500	11272.031	735.133	0.827	1.348	416.667	COMPACT	ELONGATED
11	35.000	32.000	20.000	6.500	11728.609	879.646	0.709	1.675	371.428	COMPACT	PLATY
12	40.000	35.000	25.000	6.000	18325.957	1099.557	0.764	1.500	300.000	COMPACT	BLADED
13	37.000	30.000	16.000	2.500	9299.113	871.792	0.613	2.094	135.135		BLADED
14	30.000	25.000	17.000	5.000	6675.883	589.049	0.728	1.618	333.333	COMPACT	BLADED
15	43.000	32.000	30.000	3.500	21614.156	1080.708	0.868	1.250	162.791	COMPACT	ELONGATED
16	35.000	30.000	28.000	5.400	15393.801	824.668	0.907	1.161	308.571	COMPACT	
17	37.000	36.000	30.000	7.500	20923.004	1046.150	0.877	1.217	405.405	COMPACT	
18	36.000	34.000	19.000	5.500	12176.813	961.327	0.666	1.842	305.555	COMPACT	PLATY
19	30.000	23.000	20.000	7.500	7225.660	541.925	0.834	1.325	500.000	COMPACT	ELONGATED
20	45.000	37.000	17.000	6.500	14820.461	1307.688	0.558	2.412	288.889		PLATY
21	31.000	30.000	18.000	4.500	8765.043	730.420	0.704	1.694	290.323	COMPACT	PLATY
22	35.000	24.000	21.000	9.000	9236.281	659.734	0.807	1.405	514.286	COMPACT	ELONGATED
23	36.000	32.000	19.000	5.000	11460.527	904.779	0.679	1.789	277.778	COMPACT	PLATY
24	38.000	31.000	30.000	9.500	18503.980	925.199	0.914	1.150	500.000	COMPACT	
25	41.000	40.000	23.000	7.500	19750.145	1288.053	0.686	1.761	365.854	COMPACT	PLATY
26	45.000	38.000	25.000	6.500	22383.848	1343.031	0.715	1.660	288.889	COMPACT	BLADED
27	40.000	38.000	20.000	3.500	15917.402	1193.805	0.641	1.950	175.000		PLATY
28	35.000	31.000	17.000	3.500	9657.777	852.157	0.643	1.941	200.000		PLATY
29	30.000	24.000	20.000	5.500	7539.820	565.487	0.822	1.350	366.667	COMPACT	BLADED
30	40.000	33.000	22.000	8.000	15205.305	1036.725	0.716	1.659	400.000	COMPACT	BLADED
31	36.000	34.000	31.000	9.000	19867.430	961.327	0.923	1.129	500.000	COMPACT	
32	40.000	33.000	25.000	6.500	17278.758	1036.725	0.779	1.460	325.000	COMPACT	BLADED
33	37.000	33.000	27.000	7.000	17261.480	958.971	0.842	1.296	378.378	COMPACT	
34	34.000	28.000	20.000	5.000	9969.320	747.699	0.749	1.550	294.117	COMPACT	BLADED
35	36.000	31.000	11.000	4.000	6427.695	876.504	0.477	3.045	222.222	VERY	PLATY
36	30.000	25.000	23.000	5.500	9032.078	589.049	0.890	1.196	366.667	COMPACT	
37	36.000	30.000	25.000	7.500	14137.164	848.230	0.833	1.320	416.667	COMPACT	BLADED
38	32.000	27.000	17.000	5.000	7690.617	678.584	0.694	1.735	312.500	COMPACT	BLADED
39	42.000	31.000	28.000	3.500	19088.316	1022.588	0.844	1.304	166.667	COMPACT	ELONGATED
40	24.000	20.000	17.000	9.000	4272.563	376.991	0.844	1.294	750.000	COMPACT	
41	28.000	27.000	26.000	9.500	10291.855	593.761	0.963	1.058	678.571	COMPACT	
42	40.000	36.000	18.000	2.500	13571.680	1130.973	0.608	2.111	125.000		PLATY
43	40.000	35.000	18.000	8.000	13194.688	1099.557	0.614	2.083	400.000		PLATY
44	30.000	28.000	22.000	8.500	9676.102	659.734	0.832	1.318	566.667	COMPACT	
45	40.000	39.000	25.000	7.000	20420.352	1225.221	0.737	1.580	350.000	COMPACT	PLATY
46	32.000	31.000	30.000	9.000	15582.297	779.115	0.968	1.050	562.500	COMPACT	
47	40.000	37.000	22.000	6.500	17048.375	1162.389	0.689	1.750	325.000	COMPACT	PLATY
48	34.000	27.000	20.000	3.000	9613.273	720.995	0.758	1.525	176.471	COMPACT	BLADED
49	42.000	31.000	20.000	3.500	13634.512	1022.588	0.675	1.825	166.667		BLADED
50	31.000	27.000	17.000	6.500	7450.285	657.378	0.702	1.706	419.355	COMPACT	PLATY
51	46.000	27.000	17.000	4.500	11055.262	975.464	0.615	2.147	195.652		BLADED
52	43.000	34.000	27.000	4.500	20668.535	1148.252	0.793	1.426	209.302	COMPACT	BLADED
53	54.000	38.000	24.000	9.500	25786.191	1611.637	0.655	1.917	351.852		BLADED
54	62.000	30.000	21.000	9.500	20451.766	1460.841	0.619	2.190	306.451		ELONGATED
55	53.000	47.000	18.000	9.500	23477.121	1956.427	0.507	2.778	358.490		PLATY
56	82.000	57.000	31.000	9.500	75866.313	3670.951	0.590	2.242	231.707		BLADED
57	44.000	31.000	20.000	5.500	14283.773	1071.283	0.664	1.875	250.000		BLADED
58	64.000	52.000	20.000	5.500	34850.734	2613.805	0.494	2.900	171.875	VERY	PLATY
59	44.000	24.000	18.000	5.000	9952.563	829.380	0.674	1.889	227.273		ELONGATED
60	45.000	26.000	14.000	5.000	8576.547	918.916	0.551	2.536	222.222	VERY	BLADED
61	56.000	45.000	19.000	5.500	25069.906	1979.203	0.523	2.658	196.429		PLATY
62	49.000	25.000	22.000	6.000	14110.984	962.113	0.734	1.682	244.898		ELONGATED
63	46.000	32.000	20.000	5.000	15414.746	1156.106	0.648	1.950	217.391		BLADED
64	60.000	36.000	23.000	6.000	26012.387	1696.460	0.626	2.087	200.000		BLADED
65	47.000	23.000	20.000	4.500	11320.203	849.015	0.718	1.750	191.489		ELONGATED
66	33.000	20.000	15.000	5.500	5183.625	518.363	0.699	1.767	333.333		ELONGATED
67	31.000	26.000	15.000	5.000	6330.309	633.031	0.654	1.900	322.581		PLATY
68	32.000	25.000	11.000	5.500	4607.668	628.318	0.533	2.591	343.750		BLADED
69	40.000	33.000	12.000	7.000	8293.801	1036.725	0.478	3.042	350.000	VERY	PLATY
70	50.000	25.000	22.000	6.000	14398.965	981.748	0.729	1.705	240.000		ELONGATED
71	43.000	34.000	16.000	9.000	12248.020	1148.252	0.559	2.406	418.604		BLADED
72	33.000	29.000	20.000	4.000	10021.680	751.626	0.748	1.550	242.424	COMPACT	PLATY
73	36.000	29.000	17.000	3.500	9292.828	819.956	0.652	1.912	194.444		BLADED
74	35.000	22.000	12.000	6.000	4838.051	604.756	0.572	2.375	342.857		BLADED
75	55.000	34.000	23.000	5.000	22519.980	1468.694	0.656	1.935	181.818		BLADED
76	50.000	44.000	29.000	8.000	33405.602	1727.876	0.726	1.621	320.000	COMPACT	PLATY
77	47.000	32.000	14.000	7.000	11024.895	1181.239	0.507	2.821	297.872	VERY	BLADED
78	53.000	32.000	14.000	9.000	12432.328	1332.035	0.487	3.036	339.623	VERY	BLADED
79	40.000	31.000	28.000	4.000	18179.348	973.894	0.858	1.268	200.000	COMPACT	
80	59.000	45.000	21.000	4.000	29193.246	2085.232	0.550	2.476	135.593		BLADED
81	47.000	45.000	12.000	9.000	13288.934	1661.117	0.408	3.833	382.979	VERY	PLATY
82	51.000	24.000	13.000	5.000	8331.500	961.327	0.517	2.885	196.078	VERY	ELONGATED
83	32.000	24.000	14.000	5.000	5629.730	603.186	0.634	2.000	312.500		BLADED
84	47.000	30.000	13.000	4.000	9597.563	1107.411	0.493	2.962	170.213	VERY	BLADED
85	60.000	50.000	21.000	6.000	32986.723	2356.194	0.528	2.619	200.000		PLATY
86	45.000	40.000	21.000	5.000	19792.031	1413.717	0.626	2.024	222.222		PLATY
87	51.000	30.000	23.000	8.000	18425.438	1201.659	0.702	1.761	313.725		ELONGATED
88	51.000	40.000	24.000	6.000	25635.395	1602.212	0.656	1.896	235.294		BLADED
89	53.000	41.000	26.000	7.000	29582.281	1706.670	0.678	1.808	264.151		BLADED
90	70.000	53.000	37.000	7.000	71874.375	2913.827	0.717	1.662	200.000	COMPACT	BLADED
91	62.000	54.000	22.000	5.500	38566.191	2629.513	0.525	2.636	177.419		PLATY
92	39.000	29.000	22.000	5.500	13028.184	888.285	0.754	1.545	282.051	COMPACT	BLADED
93	51.000	40.000	16.000	6.000	17090.262	1602.212	0.501	2.844	235.294	VERY	PLATY
94	95.000	55.000	30.000	8.000	82074.063	4103.703	0.556	2.500	168.421	VERY	BLADED
95	45.000	35.000	18.000	5.000	14844.023	1237.002	0.590	2.222	222.222		BLADED
96	50.000	35.000	25.000	9.000	22907.445	1374.447	0.709	1.700	360.000		BLADED
97	44.000	30.000	25.000	6.000	17278.758	1036.725	0.779	1.480	272.727	COMPACT	ELONGATED
98	45.000	35.000	21.000	8.000	17318.027	1237.002	0.654	1.905	355.555		BLADED
99	62.000	42.000	11.000	6.000	14997.961	2045.177	0.363	4.727	193.548	VERY	BLADED
100	77.000	30.000	18.000	7.000	21771.234	1814.270	0.520	2.972	181.818	VERY	ELONGATED

Table 25 Shape measurements of pebbles

PEDIMENT B SITE SIX

(II-27)

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	25.000	22.000	19.000	8.000	5471.605	431.969	0.869	1.237	640.000	COMPACT	
2	42.000	32.000	25.000	6.500	17592.918	1055.575	0.775	1.480	309.524	COMPACT	BLADED
3	51.000	47.000	17.000	7.000	21336.125	1882.599	0.494	2.882	274.510	VERY	PLATY
4	40.000	36.000	27.000	4.500	20357.520	1130.973	0.797	1.407	225.000	COMPACT	PLATY
5	26.000	21.000	20.000	8.500	5717.695	428.827	0.901	1.175	653.846	COMPACT	
6	31.000	30.000	29.000	9.500	14121.457	730.420	0.967	1.052	612.903	COMPACT	
7	27.000	26.000	25.000	7.000	9189.156	531.349	0.962	1.060	518.518	COMPACT	
8	35.000	34.000	30.000	6.500	18692.473	934.624	0.911	1.150	371.428	COMPACT	
9	25.000	24.000	22.000	9.000	6911.500	471.239	0.931	1.114	720.000	COMPACT	
10	34.000	33.000	30.000	2.500	17624.332	881.217	0.929	1.117	147.059	COMPACT	
11	29.000	23.000	21.000	4.500	7334.047	523.860	0.871	1.238	310.345	COMPACT	
12	29.000	24.000	16.000	6.500	5830.793	546.637	0.716	1.656	448.276	COMPACT	BLADED
13	25.000	23.000	20.000	5.000	6021.383	451.604	0.886	1.200	400.000	COMPACT	
14	35.000	30.000	11.000	7.500	6047.563	824.668	0.487	2.955	428.571	VERY	PLATY
15	30.000	25.000	20.000	5.000	7853.980	589.049	0.811	1.375	333.333	COMPACT	BLADED
16	26.000	25.000	21.000	8.500	7147.121	510.509	0.879	1.214	653.846	COMPACT	
17	31.000	21.000	20.000	5.500	6817.254	511.294	0.850	1.300	354.839	COMPACT	ELONGATED
18	22.000	21.000	20.000	6.500	4838.051	362.854	0.953	1.075	590.909	COMPACT	
19	30.000	25.000	23.000	6.500	9032.078	589.049	0.890	1.196	433.333	COMPACT	
20	20.000	19.000	15.000	4.000	2984.513	298.451	0.840	1.300	400.000	COMPACT	
21	30.000	29.000	17.000	6.000	7744.023	683.296	0.693	1.735	400.000	COMPACT	PLATY
22	31.000	30.000	18.000	6.500	8765.043	730.420	0.704	1.694	419.355	COMPACT	PLATY
23	27.000	25.000	15.000	3.500	5301.438	530.144	0.693	1.733	259.259	COMPACT	PLATY
24	35.000	29.000	26.000	5.000	13817.770	797.179	0.873	1.231	285.714	COMPACT	
25	36.000	30.000	25.000	4.000	14137.164	848.230	0.833	1.320	222.222	COMPACT	BLADED
26	28.000	27.000	25.000	7.500	9896.016	593.761	0.939	1.100	535.714	COMPACT	
27	35.000	34.000	26.000	6.500	16200.145	934.624	0.828	1.327	371.428	COMPACT	
28	26.000	25.000	21.000	6.500	7147.121	510.509	0.879	1.214	500.000	COMPACT	
29	26.000	23.000	16.000	4.000	5009.793	469.668	0.754	1.531	307.692	COMPACT	PLATY
30	35.000	29.000	24.000	4.500	12754.863	797.179	0.828	1.333	257.143	COMPACT	BLADED
31	31.000	27.000	25.000	6.000	10956.301	657.378	0.907	1.160	387.097	COMPACT	
32	30.000	29.000	20.000	8.500	9110.617	683.296	0.772	1.475	566.667	COMPACT	PLATY
33	26.000	23.000	13.000	5.500	4070.457	469.668	0.656	1.885	423.077		PLATY
34	36.000	36.000	10.000	2.500	6785.840	1017.876	0.426	3.600	138.889	VERY	PLATY
35	24.000	23.000	14.000	3.500	4046.371	433.540	0.708	1.679	291.667	COMPACT	PLATY
36	23.000	22.000	21.000	7.500	5563.758	397.411	0.955	1.071	652.174	COMPACT	
37	30.000	27.000	18.000	5.500	7634.066	636.172	0.737	1.583	366.667	COMPACT	PLATY
38	27.000	24.000	23.000	9.000	7803.715	508.938	0.935	1.109	666.667	COMPACT	
39	31.000	27.000	17.000	8.500	7450.285	657.378	0.702	1.706	548.387	COMPACT	PLATY
40	35.000	33.000	18.000	6.500	10885.617	907.135	0.655	1.889	371.428	COMPACT	PLATY
41	26.000	20.000	14.000	3.500	3811.799	408.407	0.722	1.643	269.231	COMPACT	BLADED
42	30.000	25.000	19.000	6.000	7461.281	589.049	0.784	1.447	400.000	COMPACT	BLADED
43	30.000	25.000	23.000	7.500	9032.078	589.049	0.890	1.196	500.000	COMPACT	
44	31.000	26.000	24.000	9.500	10128.492	633.031	0.894	1.188	612.903	COMPACT	
45	29.000	27.000	18.000	6.500	7379.598	614.967	0.745	1.556	448.276	COMPACT	PLATY
46	90.000	85.000	55.000	8.000	220304.125	6008.293	0.734	1.591	177.778	COMPACT	PLATY
47	50.000	40.000	20.000	9.000	20943.949	1570.796	0.585	2.250	360.000		BLADED
48	80.000	50.000	35.000	6.500	73303.813	3141.593	0.674	1.857	162.500		ELONGATED
49	80.000	54.000	52.000	8.500	117621.188	3392.920	0.855	1.288	212.500	COMPACT	ELONGATED
50	60.000	50.000	33.000	4.500	51836.277	2356.194	0.713	1.667	150.000	COMPACT	BLADED
51	42.000	31.000	10.000	6.500	6817.254	1022.588	0.425	3.650	309.524	VERY	BLADED
52	53.000	36.000	18.000	7.000	17982.473	1498.540	0.554	2.472	264.151		BLADED
53	38.000	30.000	23.000	6.500	13728.758	895.354	0.774	1.478	342.105	COMPACT	BLADED
54	45.000	36.000	18.000	5.500	15268.137	1272.345	0.585	2.250	244.444		BLADED
55	40.000	27.000	12.000	3.500	6785.840	848.230	0.511	2.792	175.000	VERY	BLADED
56	48.000	27.000	20.000	5.500	13571.680	1017.876	0.676	1.875	229.167		ELONGATED
57	60.000	45.000	24.000	5.000	33929.199	2120.575	0.598	2.188	166.667		BLADED
58	53.000	47.000	10.000	4.000	13042.844	1956.427	0.342	5.000	150.943	VERY	PLATY
59	52.000	34.000	22.000	4.600	20365.895	1388.584	0.649	1.955	176.923		BLADED
60	70.000	49.000	26.000	5.400	46694.535	2693.916	0.582	2.288	154.286		BLADED
61	67.000	35.000	24.000	5.500	29468.137	1841.759	0.626	2.125	164.179		ELONGATED
62	65.000	31.000	22.000	4.500	23211.133	1582.577	0.622	2.182	138.462		ELONGATED
63	70.000	56.000	18.000	6.000	36945.129	3078.761	0.436	3.500	171.429	VERY	PLATY
64	68.000	50.000	32.000	8.000	56967.543	2670.354	0.670	1.844	235.294		BLADED
65	73.000	38.000	28.000	6.000	40668.961	2178.694	0.656	1.982	164.384		ELONGATED
66	61.000	54.000	17.000	6.500	29320.480	2587.101	0.444	3.382	213.115	VERY	PLATY
67	68.000	51.000	12.000	6.000	21790.086	2723.761	0.346	4.958	176.471	VERY	PLATY
68	78.000	40.000	19.000	5.000	31038.934	2450.442	0.487	3.105	128.205	VERY	BLADED
69	48.000	38.000	13.000	6.000	12415.570	1432.566	0.453	3.308	250.000	VERY	PLATY
70	67.000	42.000	20.000	6.000	29468.137	2210.110	0.522	2.725	179.104	VERY	BLADED
71	55.000	40.000	29.000	4.500	33405.602	1727.876	0.726	1.638	163.636	COMPACT	BLADED
72	55.000	30.000	16.000	7.000	13823.004	1295.907	0.537	2.656	254.545	VERY	BLADED
73	65.000	45.000	14.000	5.000	21441.367	2297.290	0.406	3.929	153.846	VERY	BLADED
74	90.000	55.000	19.000	6.000	49244.465	3887.721	0.418	3.816	133.333	VERY	BLADED
75	90.000	45.000	22.000	8.500	46652.648	3180.863	0.493	3.068	188.889	VERY	BLADED
76	70.000	40.000	30.000	7.000	43982.297	2199.115	0.685	1.833	200.000		ELONGATED
77	65.000	55.000	37.000	5.000	69259.000	2807.798	0.726	1.622	153.846	COMPACT	BLADED
78	70.000	50.000	25.000	9.000	45814.891	2748.894	0.563	2.400	257.143		BLADED
79	75.000	40.000	20.000	5.000	31415.926	2356.194	0.511	2.875	133.333	VERY	BLADED
80	70.000	45.000	19.000	4.500	31337.387	2474.004	0.486	3.026	128.571	VERY	BLADED
81	90.000	40.000	37.000	6.000	69743.313	2827.433	0.724	1.757	133.333		ELONGATED
82	70.000	53.000	30.000	9.000	58276.543	2913.827	0.624	2.050	257.143		BLADED
83	85.000	53.000	25.000	7.500	58970.309	3538.219	0.518	2.760	176.471	VERY	BLADED
84	75.000	40.000	25.000	6.000	39269.906	2356.194	0.593	2.300	160.000	VERY	ELONGATED
85	70.000	45.000	32.000	7.000	52778.754	2474.004	0.688	1.797	200.000		BLADED
86	56.000	45.000	32.000	6.000	42223.004	1979.203	0.741	1.578	214.286	COMPACT	BLADED
87	78.000	47.000	23.000	6.000	44148.801	2879.270	0.525	2.717	153.846	VERY	BLADED
88	60.000	40.000	21.000	6.000	26389.375	1884.956	0.569	2.381	200.000		BLADED
89	65.000	45.000	19.000	8.000	29099.000	2297.290	0.498	2.895	246.154	VERY	BLADED
90	66.000	40.000	26.000	6.000	35939.816	2073.451	0.635	2.038	181.818		BLADED
91	95.000	65.000	20.000	8.000	64664.445	4849.832	0.402	4.000	168.421	VERY	BLADED
92	75.000	30.000	16.000	4.000	18849.555	1767.146	0.485	3.281	106.667	VERY	ELONGATED
93	63.000	39.000	22.000	8.000	28302.605	1929.723	0.582	2.318	253.968		BLADED
94	45.000	31.000	18.000	3.500	13147.563	1095.630	0.615	2.111	155.556		BLADED
95	40.000	30.000	11.000	4.000	6911.500	942.478	0.465	3.182	200.000	VERY	BLADED
96	30.000	20.000	10.000	4.000	3141.593	471.239	0.550	2.500	266.667	VERY	BLADED
97	80.000	45.000	27.000	5.000	50893.801	2827.433	0.587	2.315	125.000		BLADED
98	60.000	40.000	25.000	9.500	31415.926	1884.956	0.633	2.000	316.667		BLADED
99	80.000	50.000	27.000	9.500	56548.664	3141.593	0.567	2.407	237.500		BLADED
100	62.000	54.000	25.000	9.500	43825.215	2629.513	0.572	2.320	306.451		PLATY

Table 26

Lithology of pediment A pebbles

Distance	No. of Pebbles	Percent Igneous	Percent Metamorphic	Percent Limestone	Percent Other sediments
150 m.	100	00	00	98	02
400 m.	100	00	00	95	05
650 m.	100	00	00	80	20
900 m.	100	00	00	78	12
1150 m.	100	00	00	68	32

Table 27

Lithology of pediment B pebbles

Distance	No. of Pebbles	Percent Igneous	Percent Metamorphic	Percent Limestone	Percent Other sediments
100 m.	100	6	15	11	68
350 m.	100	14	16	17	53
600 m.	100	16	20	4	60
950 m.	100	30	14	20	36
1100 m.	100	43	7	29	21
1350 m.	100	44	27	6	23

Table 28

Roundness in pediment A

Distance	$\overline{X}$	σ
150 m.	256.756	106.184
400 m.	259.285	103.451
650 m.	292.282	121.236
900 m.	301.187	154.130
1150 m.	370.882	170.002
	U = 296.078	U = 131.000

(U = the mean)

Table 29

Sphericity in pediment A

Distance	$\overline{X}$	σ
150 m.	0.707	0.140
400 m.	0.723	0.152
650 m.	0.718	0.140
900 m.	0.701	0.165
1150 m.	0.735	0.137
	U = 0.717	U = 0.147

Table 30

Roundness in pediment B

Distance	$\bar{X}$	σ
100 m.	212.119	68.549
350 m.	216.691	76.743
600 m.	262.734	107.003
950 m.	264.805	129.014
1100 m.	299.470	116.860
1350 m.	299,515	155.482
	$\bar{U}$ = 259.222	$\bar{U}$ = 108.942

(U = the mean)

Table 31

Sphericity in pediment B

Distance	$\bar{X}$	σ
100 m.	0.699	0.134
350 m.	0.645	0.153
600 m.	0.678	0.145
950 m.	0.694	0.146
1100 m.	0.688	0.132
1350 m.	0.679	0.165
	$\bar{U}$ = 0.681	$\bar{U}$ = 0.146

Table 32

Percentage of form class of pebbles from pediments surface material

E = Elongated V = Very C = Compact B = Bladed P = Platy

	Distance	E %	V.E %	C.E %	Sub Total %	B %	V.B %	C.B %	Sub Total %	P %	V.P %	C.P %	Sub Total %	Compact %	Total %
Pediment A	1150 m.	7	2	12	21	13	6	16	35	13	6	6	25	19	100
	900 m.	8	2	10	20	16	10	12	38	7	2	5	14	28	100
	650 m.	7	2	4	13	12	7	16	35	15	2	8	25	27	100
	400 m.	5	2	4	10	20	5	13	38	10	3	8	21	30	100
	150 m.	9	4	7	20	12	14	12	38	5	5	7	17	25	100
	total	36	12	37	84	73	42	96	184	50	18	34	102	129	500
	%	7.2	2.4	7.4	17.0	14.6	8.4	13.8	36.8	10.0	3.6	6.8	20.4	25.8	100
Pediment B	1350 m.	12	6	9	27	17	10	14	41	7	2	7	16	16	100
	1100 m.	9	2	8	19	14	10	16	40	10	7	12	29	12	100
	950 m.	9	3	7	19	19	12	8	39	13	0	6	19	23	100
	600 m.	7	2	8	17	20	6	16	42	11	6	12	29	12	100
	350 m.	7	2	2	11	17	16	12	45	2	8	12	22	22	100
	100 m.	4	4	5	13	10	20	11	41	6	12	15	33	13	100
	total	48	19	39	106	97	74	77	248	49	35	64	148	98	600
	%	8.0	3.16	6.5	17.66	16.16	12.33	12.83	41.33	8.16	5.83	10.66	24.66	16.33	100

Table 33

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-2 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$		11.95	-29.87	-4	-47.8	191.2	-764.8	3059.20	7468.75
$\overline{2}$ - $\overline{1}$	$\overline{1}.5$	11.55	-17.32	-3	-34.65	103.95	-311.85	935.55	2956.80
$\overline{1}$ - 0	$\overline{0}.5$	6.76	-3.38	-2	-13.52	27.04	-54.08	108.16	547.56
0 - 1	0.5	5.23	2.61	-1	-5.23	5.23	-5.23	5.23	83.68
1 - 2	X_o = 1.5	22.62	33.93	0	0.00	0.00	0.00	0.00	22.62
2 - 3	2.5	20.71	51.77	1	20.71	20.71	20.71	20.71	0.00
3 - 4	3.5	15.37	53.79	2	30.74	61.48	122.96	245.92	15.37
4 - 5	4.5	4.26	19.17	3	12.78	38.34	115.02	345.06	68.16
5 - 6	5.5	0.50	2.75	4	2.00	8.00	32.00	128.00	40.50
6 - 7	6.5	0.50	3.25	5	2.50	12.50	62.50	312.50	128.00
7 - 8	7.5	0.00		6	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.55	4.67	7	3.50	24.50	171.50	1200.50	648.00
9		0.00		8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	121.37		-28.97	492.95	-611.27	6360.83	11979.44
moments around the arbitrary origin					n_1 = -0.2897	n_2 = 4.9295	n_3 = -6.1127	n_4 = 63.6083	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\bar{X}_o = 1.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.213 \qquad m_1 = \bar{X} = X_o + cn_1 = 1.2103$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.8456 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 15.4744$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 58.9855 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.2012$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 1.4509 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.7254$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.5125 \qquad K = b_2 - 3 = -0.4875$$

Summary: $\bar{X} = 1.2103$ $M_\phi = 1.213$ $\sigma_\phi = 2.2012$ $SK = 0.7254$

$\sqrt{b_1} = 1.4509$ $b_2 = 2.5125$ $K = -0.4875$

Table 34

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-3 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		11.89	-29.72	-5	-59.45	297.25	-1486.25	7431.25	15409.44
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	10.33	-15.49	-4	-41.32	165.28	-661.12	2644.48	6456.25
$\bar{1}$ - 0	$\bar{0}$.5	5.45	-2.72	-3	-16.35	49.05	-147.15	441.45	1395.20
0 - 1	0.5	3.59	1.79	-2	-7.18	14.36	-28.72	57.44	290.79
1 - 2	1.5	19.80	29.70	-1	-19.80	19.80	19.80	19.80	316.80
2 - 3	X_o = 2.5	22.42	56.05	0	0.00	0.00	0.00	0.00	0.00
3 - 4	3.5	13.33	46.65	1	13.33	13.33	13.33	13.33	0.00
4 - 5	4.5	4.13	18.58	2	8.26	16.52	33.04	66.08	4.13
5 - 6	5.5	3.50	19.25	3	10.50	31.50	94.50	283.50	56.00
6 - 7	6.5	0.50	3.25	4	2.00	8.00	32.00	128.00	40.50
7 - 8	7.5	1.50	11.25	5	7.50	37.50	187.50	937.50	384.00
8 - 9	8.5	0.50	4.25	6	3.00	18.00	108.00	648.00	312.50
$\bar{9}$		3.06	29.07	7	21.42	149.94	1049.58	7347.06	3965.76
Total	Σ	100	171.91		-78.09	820.53	-280.94	19757.09	28631.37
moments around the arbitrary origin					n_1 = -0.781	n_2 = 8.21	n_3 = -2.809	n_4 = 197.571	

m = midpoint of each class   f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\bar{X}_o = 2.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.71$ $m_1 = X = X_o + cn_1 = 1.719$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.6001$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -2.7043$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 217.7236$ $\sigma_\phi = \sqrt{\sigma^2} = 2.7568$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.129$ $SK = \frac{\sqrt{b_1}}{2} = -0.0645$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.7695$ $K = b_2 - 3 = 0.7695$

Summary: $\bar{X} = 1.719$ $M_\phi = 1.719$ $\sigma_\phi = 2.7568$ $SK = -0.0645$

$\sqrt{b_1} = -0.129$ $b_2 = 3.7695$ $K = 0.7695$

Table 35

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-4 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		17.33	-43.32	-5	-86.65	433.25	-2166.25	10831.25	22459.68
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	17.79	-26.68	-4	-71.16	284.64	-1138.56	4554.24	11118.75
$\bar{1}$ - 0	$\bar{0}.5$	8.89	-4.44	-3	-26.67	80.01	-240.03	720.09	2275.84
0 - 1	0.5	4.47	2.23	-2	-8.94	17.88	-35.76	71.52	362.07
1 - 2	1.5	8.71	13.06	-1	-8.71	8.71	-8.71	8.71	139.36
2 - 3	X_o = 2.5	22.92	57.30	0	0.00	0.00	0.00	0.00	22.92
3 - 4	3.5	11.08	38.78	1	11.08	11.08	11.08	11.08	0.00
4 - 5	4.5	2.91	13.09	2	5.82	11.64	23.28	46.56	2.91
5 - 6	5.5	2.06	11.33	3	6.18	18.54	55.62	166.86	32.96
6 - 7	6.5	1.54	10.01	4	6.16	24.64	98.56	394.24	124.74
7 - 8	7.5	1.03	7.72	5	5.15	25.75	128.75	643.75	263.68
8 - 9	8.5	0.00		6	0.00	0.00	0.00	0.00	0.00
$\bar{9}$		1.27	12.06	7	8.89	62.23	435.61	3049.27	1645.92
Total	Σ		91.14		-158.85	718.37	-2892.03	20497.57	38448.83
moments around the arbitrary origin					n_1 = -1.588	n_2 = 7.184	n_3 = -28.92	n_4 = 204.97	

m = midpoint of each class   f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 2.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.91$ $m_1 = X = X_o + cn_1 = 0.912$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.6623$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -1.2939$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 110.8888$ $\sigma_\phi = \sqrt{\sigma^2} = 2.1592$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.1285$ $SK = \frac{\sqrt{b_1}}{2} = -0.0642$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 5.1017$ $K = b_2 - 3 = 2.1017$

Summary: $\bar{X} = 0.912$ $M_\phi = 0.91$ $\sigma_\phi = 2.1592$ SK = -0.0642

$\sqrt{b_1} = -0.1285$ $b_2 = 5.1017$ $K = 2.1017$

Table 36

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-5 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		9.60	-24.0	-5	-48.00	240.00	-1200.00	6000.00	12441.60
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	12.26	-18.39	-4	-49.04	196.16	-784.64	3138.56	7662.50
$\bar{1}$ - 0	$\bar{0}.5$	6.42	3.21	-3	-19.26	57.78	-173.34	520.02	1643.52
0 - 1	0.5	3.16	1.58	-2	-6.32	12.64	-25.28	50.56	255.96
1 - 2	1.5	8.80	13.20	-1	-8.80	8.80	-8.80	8.80	140.80
2 - 3	X_0=2.5	25.43	63.57	0	0.00	0.00	0.00	0.00	25.43
3 - 4	3.5	17.41	60.93	1	17.41	17.41	17.41	17.41	0.00
4 - 5	4.5	10.20	45.90	2	20.40	40.80	81.60	163.20	10.20
5 - 6	5.5	3.51	19.30	3	10.53	31.59	94.77	284.31	56.16
6 - 7	6.5	1.00	6.50	4	4.00	16.00	64.00	256.00	81.00
7 - 8	7.5	1.00	7.50	5	5.00	25.00	125.00	625.00	256.00
8 - 9	8.5	0.50	4.25	6	3.00	18.00	108.00	648.00	312.50
$\bar{9}$		0.71	6.74	7	4.97	34.79	243.53	1704.71	920.16
Total	Σ	100	183.87		-66.11	698.97	-1457.75	13416.57	23805.83
moments around the arbitrary origin					n_1 = -0.661	n_2 = 6.9897	n_3 = -14.577	n_4 = 134.165	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = 2.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.83$ $m_1 = X = X_o + cn_1 = 1.839$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.5528$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.9848$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 113.3738$ $\sigma_\phi = \sqrt{\sigma^2} = 2.5598$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0587$ $SK = \frac{\sqrt{b_1}}{2} = 0.0293$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.6405$ $K = b_2 - 3 = -0.3595$

Summary: $\overline{X} = 1.839$ $M_\phi = 1.83$ $\sigma_\phi = 2.5598$ $SK = 0.0293$

$\sqrt{b_1} = 0.0587$ $b_2 = 2.6405$ $K = -0.3595$

Table 37

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-6 from Pediment A at Khashm Qraydan area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$		2.36	-5.90	-5	-11.80	59.00	-295.00	1475.00	3058.56
$\overline{2}$ - $\overline{1}$	$\overline{1}.5$	3.89	-5.83	-4	-15.56	62.24	-248.96	995.84	2431.25
$\overline{1}$ - 0	$\overline{0}.5$	2.85	-1.42	-3	-8.55	25.65	-76.95	230.85	729.60
0 - 1	0.5	2.47	1.23	-2	-4.94	9.88	-19.76	39.52	200.07
1 - 2	1.5	12.50	18.75	-1	-12.50	12.50	-12.50	12.50	200.00
2 - 3	X_o=2.5	29.42	73.55	0	0.00	0.00	0.00	0.00	29.42
3 - 4	3.5	24.72	86.52	1	24.72	24.72	24.72	24.72	0.00
4 - 5	4.5	12.57	56.56	2	25.14	50.28	100.56	201.12	12.57
5 - 6	5.5	4.03	22.16	3	12.09	36.27	108.81	326.43	64.48
6 - 7	6.5	2.01	13.06	4	8.04	32.16	128.64	514.56	162.81
7 - 8	7.5	1.00	7.50	5	5.00	25.00	125.00	625.00	256.00
8 - 9	8.5	1.00	8.50	6	6.00	36.00	216.00	1296.00	625.00
$\overline{9}$		1.18	11.21	7	8.26	57.82	404.74	2833.18	1529.28
Total	Σ	100	285.89		27.90	431.52	455.30	8574.72	9299.04
moments around the arbitrary origin					n_1 = 0.279	n_2 = 4.315	n_3 = 4.553	n_4 = 85.747	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = 2.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.85 \qquad m_1 = X = X_o + cn_1 = 2.779$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.2372 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 11.2014$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 82.6621 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.0584$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 1.2843 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.6421$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.6045 \qquad K = b_2 - 3 = 1.6045$$

Summary: $\overline{X} = 2.779$ $M_\phi = 2.85$ $\sigma_\phi = 2.0584$ $SK = 0.6421$

$\sqrt{b_1} = 1.2843$ $b_2 = 4.6045$ $K = 1.6045$

Table 38

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-8 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.95	-1.42	-5	-4.75	23.75	-118.75	593.75	1231.20
$\bar{1}$ - 0	$\bar{0}$.5	2.63	-1.31	-4	-10.52	42.08	-168.32	673.28	1643.75
0 - 1	0.5	6.87	3.43	-3	-20.61	61.83	-185.49	556.47	1758.72
1 - 2	1.5	7.32	10.98	-2	-14.64	29.28	-58.56	117.12	592.92
2 - 3	2.5	18.08	45.20	-1	-18.08	18.08	-18.08	18.08	289.28
3 - 4	X_o=3.5	30.16	105.56	0	0.00	0.00	0.00	0.00	30.16
4 - 5	4.5	11.28	50.76	1	11.28	11.28	11.28	11.28	0.00
5 - 6	5.5	3.81	20.95	2	7.62	15.24	30.48	60.96	3.81
6 - 7	6.5	1.90	12.35	3	5.70	17.10	51.30	153.90	30.40
7 - 8	7.5	6.68	50.10	4	26.72	106.88	427.52	1710.08	541.08
8 - 9	8.5	2.86	24.31	5	14.30	71.50	357.50	1787.50	732.16
$\bar{9}$		7.46	70.87	6	44.76	268.56	1611.36	9668.16	4662.50
Total	Σ	100	391.78		41.78	665.58	1940.24	15350.58	11515.98
moments around the arbitrary origin					n_1 = 0.418	n_2 = 6.656	n_3 = 19.402	n_4 = 153.506	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = 3.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 3.91$

$m_1 = X = X_o + cn_1 = 3.918$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.4813$

$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 8.3556$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 127.9512$

$\sigma_\phi = \sqrt{\sigma^2} = 2.5458$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.5064$

$SK = \frac{\sqrt{b_1}}{2} = 0.2532$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.0461$

$K = b_2 - 3 = 0.0461$

Summary: $\bar{X} = 3.918$ $M_\phi = 3.91$ $\sigma_\phi = 2.5458$ $SK = 0.2532$

$\sqrt{b_1} = 0.5064$ $b_2 = 3.0461$ $K = 0.0461$

Table 39

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-9 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
$\bar{2} - \bar{1}$	$\bar{1}.5$	1.01	-1.51	-5	-5.05	25.25	-126.25	631.25	1308.96
$\bar{1} - 0$	$\bar{0}.5$	8.11	-4.05	-4	-32.44	129.76	-519.04	2076.16	5068.75
0 - 1	0.5	14.63	7.31	-3	-43.89	131.67	-395.01	1185.03	3745.28
1 - 2	1.5	13.53	20.29	-2	-27.06	54.12	-108.24	216.48	1095.93
2 - 3	2.5	23.97	59.92	-1	-23.97	23.97	-23.97	23.97	383.52
3 - 4	X_o=3.5	27.20	95.20	0	0.00	0.00	0.00	0.00	27.20
4 - 5	4.5	4.41	19.84	1	4.41	4.41	4.41	4.41	0.00
5 - 6	5.5	2.33	12.81	2	4.66	9.32	18.64	37.28	2.33
6 - 7	6.5	0.93	6.04	3	2.79	8.37	25.11	75.33	14.88
7 - 8	7.5	0.93	6.97	4	3.72	14.88	59.52	238.08	75.33
8 - 9	8.5	0.46	3.91	5	2.30	11.50	57.50	287.50	117.76
$\bar{9}$		2.49	23.65	6	14.94	89.64	537.84	3227.04	1556.25
Total	Σ	100	250.38		-99.59	502.89	-469.49	8002.53	13396.19
moments around the arbitrary origin					n_1 = -0.996	n_2 = 5.029	n_3 = -4.695	n_4 = 80.025	

m = midpoint of each class $\qquad$ f = frequency $\qquad$ $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean $\qquad$ M_ϕ = logarithmetic mean $\qquad$ c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\qquad$ σ_ϕ = standard deviation $\qquad$ K = kurtosis $\qquad$ $X_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.50 \qquad m_1 = X = X_o + cn_1 = 2.504$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.037 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.5615$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 88.3008 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.0092$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0692 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.0346$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 5.4185 \qquad K = b_2 - 3 = 2.4185$$

Summary: $\overline{X} = 2.504$ $\qquad$ $M_\phi = 2.50$ $\qquad$ $\sigma_\phi = 2.0092$ $\qquad$ SK = 0.0346

$\sqrt{b_1} = 0.0692$ $\qquad$ $b_2 = 5.4185$ $\qquad$ K = 2.4185

Table 40

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-11 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		7.33	-18.32	-6	-43.98	263.88	-1583.28	9499.68	17599.33
$\bar{2} - \bar{1}$	$\bar{1}.5$	16.48	-24.72	-5	-82.40	412.0	-2060.0	10300.0	21358.08
$\bar{1} - 0$	$\bar{0}.5$	13.39	-6.64	-4	-53.56	214.24	-856.96	3427.84	8368.75
0 - 1	0.5	7.21	3.60	-3	-21.63	64.89	-194.67	584.01	1845.76
1 - 2	1.5	7.11	10.66	-2	-14.22	28.44	-56.88	113.76	575.91
2 - 3	2.5	18.10	45.25	-1	-18.10	18.10	-18.10	18.10	289.60
3 - 4	X_0=3.5	20.09	70.31	0	0.00	0.00	0.00	0.00	20.09
4 - 5	4.5	8.15	36.67	1	8.15	8.15	8.15	8.15	0.00
5 - 6	5.5	0.80	4.40	2	1.60	3.20	6.40	12.80	0.80
6 - 7	6.5	0.40	2.60	3	1.20	3.60	10.80	32.40	6.40
7 - 8	7.5	0.40	3.00	4	1.60	6.40	25.60	102.40	32.40
8 - 9	8.5	0.54	4.59	5	2.70	13.50	67.50	337.50	138.24
$\bar{9}$		0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	131.98		-218.64	1036.40	-4651.44	24436.64	50202.96
moments around the arbitrary origin					n_1 =	n_2 =	n_3 =	n_4 =	
					-2.186	10.364	-46.514	244.366	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\bar{X}_o = 3.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.32$ $m_1 = X = X_o + cn_1 = 1.314$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.5855$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.0089$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 66.2903$ $\sigma_\phi = \sqrt{\sigma^2} = 2.3633$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0006$ $SK = \frac{\sqrt{b_1}}{2} = 0.0003$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.1251$ $K = b_2 - 3 = -0.8749$

Summary: $\bar{X} = 1.314$ $M_\phi = 1.32$ $\sigma_\phi = 2.3633$ SK = 0.0003

$\sqrt{b_1} = 0.0006$ $b_2 = 2.1251$ K = -0.8749

Table 41

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-12 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-4	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-3	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	0.95	-0.47	-2	-1.90	3.80	-7.60	15.20	76.95
0 - 1	0.5	8.11	4.05	-1	-8.11	8.11	-8.11	8.11	129.76
1 - 2	X_o=1.5	33.48	50.22	0	0.00	0.00	0.00	0.00	33.48
2 - 3	2.5	32.73	81.82	1	32.73	32.73	32.73	32.73	0.00
3 - 4	3.5	21.46	75.11	2	42.92	85.84	171.68	343.36	21.46
4 - 5	4.5	3.27	14.71	3	9.81	29.43	88.29	264.87	52.32
5 - 6	5.5	0.00	0.00	4	0.00	0.00	0.00	0.00	0.00
6 - 7	6.5	0.00	0.00	5	0.00	0.00	0.00	0.00	0.00
7 - 8	7.5	0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
$\bar{9}$		0.00	0.00	8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	225.44		75.45	159.91	276.99	664.27	313.97
moments around the arbitrary origin					n_1 = 0.755	n_2 = 1.599	n_3 = 2.77	n_4 = 6.643	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 1.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.25 \qquad m_1 = X = X_o + cn_1 = 2.255$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 1.029 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 2.3816$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 2.7717 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.0143$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 2.2823 \qquad SK = \frac{\sqrt{b_1}}{2} = 1.1411$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.6187 \qquad K = b_2 - 3 = 0.3813$$

Summary: $\bar{X} = 2.255$ $M_\phi = 2.25$ $\sigma_\phi = 1.0143$ $SK = 1.1411$

$\sqrt{b_1} = 2.2823$ $b_2 = 2.6187$ $K = 0.3813$

Table 42

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-13 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.45	-0.67	-5	-2.25	11.25	-56.25	281.25	583.20
$\bar{1}$ - 0	$\bar{0}$.5	12.05	-6.02	-4	-48.20	192.80	-771.20	3084.80	7531.25
0 - 1	0.5	18.43	9.21	-3	-55.29	165.87	-497.61	1492.83	4718.08
1 - 2	1.5	11.73	17.59	-2	-23.46	46.92	-93.84	187.68	950.13
2 - 3	2.5	22.17	55.42	-1	-22.17	22.17	-22.17	22.17	354.72
3 - 4	$\bar{X}_o$=3.5	29.45	103.07	0	0.00	0.00	0.00	0.00	29.45
4 - 5	4.5	2.06	9.27	1	2.06	2.06	2.06	2.06	0.00
5 - 6	5.5	1.32	7.26	2	2.64	5.28	10.56	21.12	1.32
6 - 7	6.5	0.88	5.72	3	2.64	7.92	23.76	71.28	14.08
7 - 8	7.5	0.44	3.30	4	1.76	7.04	26.16	112.64	35.64
8 - 9	8.5	1.02	8.67	5	5.10	25.50	127.50	637.50	261.12
$\bar{9}$		0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	212.82		-137.17	486.81	-1249.03	5891.30	14478.99
moments around the arbitrary origin					n_1 = -1.372	n_2 = 4.868	n_3 = -12.490	n_4 = 58.913	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f} \quad n_2 = \frac{\Sigma fd^2}{\Sigma f} \quad n_3 = \frac{\Sigma fd^3}{\Sigma f} \quad n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.128 \qquad m_1 = X = X_o + cn_1 = 2.128$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.9857 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 2.8901$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 34.7168 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.7279$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.5602 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.2801$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.8947 \qquad K = b_2 - 3 = 0.8947$$

Summary: $\quad$ $\bar{X} = 2.128$ $\quad$ $M_\phi = 2.13$ $\quad$ $\sigma_\phi = 1.7279$ $\quad$ SK = 0.2801

$\sqrt{b_1} = 0.5602$ $\quad$ $b_2 = 3.8947$ $\quad$ K = 0.8947

Table 43

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-14 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-2	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.63	-0.94	-1	-0.63	0.63	-0.63	0.63	10.08
$\bar{1}$ - 0	$X_o=\bar{0}.5$	51.58	-25.79	0	0.00	0.00	0.00	0.00	51.58
0 - 1	0.5	32.83	16.41	1	32.83	32.83	32.83	32.83	0.00
1 - 2	1.5	3.56	5.34	2	7.12	14.24	28.48	56.96	3.56
2 - 3	2.5	5.31	13.27	3	15.93	47.79	143.37	430.11	84.96
3 - 4	3.5	5.08	17.78	4	20.32	81.28	325.12	1300.48	411.48
4 - 5	4.5	0.73	3.28	5	3.65	18.25	91.25	456.25	186.88
5 - 6	5.5	0.28	1.54	6	1.68	10.08	60.48	362.88	175.00
6 - 7	6.5	0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
7 - 8	7.5	0.00	0.00	8	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	9	0.00	0.00	0.00	0.00	0.00
$\bar{9}$		0.00	0.00	10	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	30.89		80.90	205.10	680.93	2640.14	923.54
moments around the arbitrary origin					$n_1 =$ 0.809	$n_2 =$ 2.051	$n_3 =$ 6.809	$n_4 =$ 26.401	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = -0.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.30$ $m_1 = X = X_o + cn_1 = 0.309$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 1.3966$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.2917$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 11.1355$ $\sigma_\phi = \sqrt{\sigma^2} = 1.1817$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.1767$ $SK = \frac{\sqrt{b_1}}{2} = 0.0883$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 5.7108$ $K = b_2 - 3 = 2.7108$

Summary: $\bar{X} = 0.309$ $M_\phi = 0.30$ $\sigma_\phi = 1.1817$ $SK = 0.0883$

$\sqrt{b_1} = 0.1767$ $b_2 = 5.7108$ $K = 2.7108$

Table 44

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-18 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-4	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.00	0.00	-3	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}$.5	0.00	0.00	-2	0.00	0.00	0.00	0.00	0.00
0 - 1	0.5	0.08	0.04	-1	-0.08	0.08	-0.08	0.08	1.28
1 - 2	X_o=1.5	45.23	67.84	0	0.00	0.00	0.00	0.00	45.23
2 - 3	2.5	39.93	99,82	1	39.93	39.93	39.93	39.93	0.00
3 - 4	3.5	13.38	46.83	2	26.76	53.52	107.04	214.08	13.38
4 - 5	4.5	1.38	6.21	3	4.14	12.42	37.26	111.78	22.08
5 - 6	5.5	0.00	0.00	4	0.00	CO.00	0.00	0.00	0.00
6 - 7	6.5	0.00	0.00	5	0.00	0.00	0.00	0.00	0.00
7 - 8	7.5	0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
$\bar{9}$		0.00	0.00	8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	220.74		70.75	106.36	184.15	365.87	81.97
moments around the arbitrary origin					n_1 = 0.708	n_2 = 1.064	n_3 = 1.842	n_4 = 3.659	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $\quad$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $\quad$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $\quad$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $X_o = 1.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.20$ $\quad$ $m_1 = X = X_o + cn_1 = 2.2080$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 0.5628$ $\quad$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.2917$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 0.8888$ $\quad$ $\sigma_\phi = \sqrt{\sigma^2} = 0.7501$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.6912$ $\quad$ $SK = \frac{\sqrt{b_1}}{2} = 0.3456$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.8082$ $\quad$ $K = b_2 - 3 = -0.1918$

Summary: $\bar{X} = 2.208$ $\quad$ $M_\phi = 2.20$ $\quad$ $\sigma_\phi = 0.7501$ $\quad$ $SK = 0.3456$

$\sqrt{b_1} = 0.6912$ $\quad$ $b_2 = 2.8082$ $\quad$ $K = -0.1918$

Table 45

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-23 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		10.50	-26.25	-6	-63.0	378.0	-2268.0	13608.0	25210.50
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	13.26	-19.89	-5	-66.3	331.5	-1657.5	8287.5	17184.96
$\bar{1}$ - 0	$\bar{0}.5$	15.22	-7.61	-4	-60.88	243.52	-974.08	3896.32	9512.50
0 - 1	0.5	8.63	4.31	-3	-25.89	77.67	-233.01	699.03	2209.28
1 - 2	1.5	10.01	15.01	-2	-20.02	40.04	-80.08	160.16	810.81
2 - 3	2.5	11.71	29.27	-1	-11.71	11.71	-11.71	11.71	187.36
3 - 4	$\bar{X}_o$=3.5	24.19	84.66	0	0.00	0.00	0.00	0.00	24.19
4 - 5	4.5	4.80	21.60	1	4.80	4.80	4.80	4.80	0.00
5 - 6	5.5	0.99	5.44	2	1.98	3.96	7.92	15.84	0.99
6 - 7	6.5	0.69	4.48	3	2.07	6.21	18.63	55.89	11.04
7 - 8	7.5	0.00	0.00	4	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	5	0.00	0.00	0.00	0.00	0.00
$\bar{9}$		0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	111.02		-238.95	1097.41	-5193.03	26739.25	55151.63
moments around the arbitrary origin					n_1 = -2.39	n_2 = 10.974	n_3 = -51.93	n_4 = 267.393	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f}$ $\quad$ $n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f}$ $\quad$ $n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f}$ $\quad$ $n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 3.5$

$M_\phi = \frac{\Sigma\ fm}{\Sigma f} = 1.11$ $\quad$ $m_1 = X = X_o + cn_1 = 1.11$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.2619$ $\quad$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.5503$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 49.1657$ $\quad$ $\sigma_\phi = \sqrt{\sigma^2} = 2.2938$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0455$ $\quad$ $SK = \frac{\sqrt{b_1}}{2} = -0.0227$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 1.7759$ $\quad$ $K = b_2 - 3 = -1.2241$

Summary: $\bar{X} = 1.11$ $\quad$ $M_\phi = 1.11$ $\quad$ $\sigma_\phi = 2.2938$ $\quad$ SK = -0.0227

$\sqrt{b_1} = -0.0455$ $\quad$ $b_2 = 1.7759$ $\quad$ K = -1.2241

Table 46

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-24 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		16.99	-42.47	-6	-101.94	611.64	-3669.84	22019.04	40792.99
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	1.71	-2.56	-5	-8.55	42.75	-213.75	1068.75	2216.16
$\bar{1}$ - 0	$\bar{0}$.5	0.94	-0.47	-4	-3.76	15.04	-60.16	240.64	587.50
0 - 1	0.5	1.22	0.61	-3	-3.66	10.98	-32.94	98.82	312.32
1 - 2	1.5	4.90	7.35	-2	-9.80	19.60	-39.20	78.40	396.90
2 - 3	2.5	10.65	26.62	-1	-10.65	10.65	-10.65	10.65	170.40
3 - 4	X_0=3.5	25.14	87.99	0	0.00	0.00	0.00	0.00	25.14
4 - 5	4.5	21.40	96.30	1	21.40	21.40	21.40	21.40	0.00
5 - 6	5.5	2.00	11.00	2	4.0	8.0	16.0	32.0	2.00
6 - 7	6.5	2.00	13.00	3	6.0	18.0	54.0	162.0	32.0
7 - 8	7.5	5.50	41.25	4	22.0	88.0	352.0	1408.0	445.50
8 - 9	8.5	3.00	25.50	5	15.0	75.0	375.0	1875.0	768.00
$\bar{9}$		4.55	43.22	6	27.30	163.80	982.80	5896.80	2843.75
Total	Σ	100	307.34		-42.66	1084.86	-4026.54	32911.50	48592.66
moments around the arbitrary origin					n_1 = -0.427	n_2 = 10.849	n_3 = -40.265	n_4 = 329.115	

m = midpoint of each class   f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 3.07 \qquad m_1 = X = X_o + cn_1 = 3.073$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 10.6667 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -26.5231$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 272.1094 \qquad \sigma_\phi = \sqrt{\sigma^2} = 3.2659$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.7614 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.3807$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.3918 \qquad K = b_2 - 3 = -0.6082$$

Summary: $\bar{X} = 3.073$ $M_\phi = 3.07$ $\sigma_\phi = 3.2659$ $SK = -0.3807$

$\sqrt{b_1} = -0.7614$ $b_2 = 2.3918$ $K = -0.6082$

Table 47

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-25 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.71	-1.77	-5	-3.55	17.75	-88.75	443.75	920.16
$\bar{2} - \bar{1}$	$\bar{1}.5$	3.05	-4.57	-4	-12.20	48.80	-195.20	780.80	1906.25
$\bar{1} - 0$	$\bar{0}.5$	2.73	-1.36	-3	-8.19	24.57	-73.71	221.13	698.88
0 - 1	0.5	3.65	1.82	-2	-7.30	14.60	-29.20	58.40	295.65
1 - 2	1.5	18.76	28.14	-1	-18.76	18.76	-18.76	18.76	300.16
2 - 3	X_0=2.5	36.49	91.22	0	0.00	0.00	0.00	0.00	36.49
3 - 4	3.5	26.66	93.31	1	26.66	26.66	26.66	26.66	0.00
4 - 5	4.5	3.93	17.68	2	7.86	15.72	31.44	62.88	3.93
5 - 6	5.5	1.49	8.19	3	4.47	13.41	40.23	120.69	23.84
6 - 7	6.5	0.49	3.18	4	1.96	7.84	31.36	125.44	39.69
7 - 8	7.5	0.99	7.42	5	4.95	24.75	123.75	618.75	253.44
8 - 9	8.5	0.49	4.16	6	2.94	17.64	105.84	635.04	306.25
$\bar{9}$		0.56	5.32	7	3.92	27.44	192.08	1344.56	725.76
Total	Σ	100	252.74		2.76	257.94	+405.62	4456.86	5510.50
moments around the arbitrary origin					n_1 = 0.028	n_2 = 2.579	n_3 = +4.056	n_4 = 44.568	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = 2.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.52$ $m_1 = \overline{X} = X_o + cn_1 = 2.528$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.5783$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 3.8394$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 44.1246$ $\sigma_\phi = \sqrt{\sigma^2} = 1.6057$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.9274$ $SK = \frac{\sqrt{b_1}}{2} = 0.4637$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 6.638$ $K = b_2 - 3 = 3.638$

Summary: $\overline{X} = 2.528$ $M_\phi = 2.52$ $\sigma_\phi = 1.6057$ $SK = 0.4637$

$\sqrt{b_1} = 0.9274$ $b_2 = 6.638$ $K = 3.638$

Table 48

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-26 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		3.33	-8.33	-6	-19.98	119.88	-719.28	4315.68	7995.33
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	3.69	-5.54	-5	-18.45	92.25	-461.25	2306.25	4782.24
$\bar{1}$ - 0	$\bar{0}$.5	4.30	-2.15	-4	-17.20	68.80	-275.20	1100.80	2687.50
0 - 1	0.5	4.28	2.14	-3	-12.84	38.52	-115.56	346.68	1095.68
1 - 2	1.5	9.91	14.87	-2	-19.82	39.64	-79.28	158.56	802.71
2 - 3	2.5	15.18	37.95	-1	-15.18	15.18	-15.18	15.18	242.88
3 - 4	X_o=3.5	25.87	90.55	0	0.00	0.00	0.00	0.00	25.87
4 - 5	4.5	8.98	40.41	1	8.98	8.98	8.98	8.98	0.00
5 - 6	5.5	4.70	25.85	2	9.40	18.80	37.60	75.20	4.70
6 - 7	6.5	2.82	18.33	3	8.46	25.38	76.14	228.42	45.12
7 - 8	7.5	6.11	45.83	4	24.44	97.76	391.04	1564.16	494.91
8 - 9	8.5	4.23	35.96	5	21.15	105.75	528.75	2643.75	1082.88
$\bar{9}$		6.60	62.70	6	39.60	237.60	1425.60	8553.60	4125.00
Total	Σ	100	360.72		8.56	868.54	802.36	21317.26	23384.82
moments around the arbitrary origin					n_1 = 0.086	n_2 = 8.685	n_3 = 8.024	n_4 = 213.173	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

X_{ϕ} = assumed mean M_{ϕ} = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_{ϕ} = standard deviation   K = kurtosis $X_o = 3.5$

$M_{\phi} = \frac{\Sigma fm}{\Sigma f} = 3.60$ $m_1 = X = X_o + cn_1 = 3.586$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 8.6777$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 5.7845$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 210.7932$ $\sigma_{\phi} = \sqrt{\sigma^2} = 2.9457$

$\sqrt{b_1} = \frac{m_3}{\sigma_{\phi}^3} = 0.2263$ $SK = \frac{\sqrt{b_1}}{2} = 0.1131$

$b_2 = \frac{m_4}{\sigma_{\phi}^4} = 2.7996$ $K = b_2 - 3 = -0.2004$

Summary: $\overline{X} = 3.586$ $M_{\phi} = 3.6$ $\sigma_{\phi} = 2.9457$ SK = 0.1131

$\sqrt{b_1} = 0.2263$ $b_2 = 2.7996$ K = -0.2004

Table 49a

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-27a from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-8	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-7	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
0 - 1	0.5	0.27	0.13	-5	-1.35	6.75	-33.75	168.75	349.92
1 - 2	1.5	0.48	0.72	-4	-1.92	7.68	-30.72	122.88	300.00
2 - 3	2.5	1.29	3.22	-3	-3.87	11.61	-34.83	104.49	330.24
3 - 4	3.5	4.59	16.06	-2	-9.18	18.36	-36.72	73.44	371.79
4 - 5	4.5	27.49	123.70	-1	-27.49	27.49	-27.49	27.49	439.84
5 - 6	X_o=5.5	31.80	174.90	0	0.00	0.00	0.00	0.00	31.80
6 - 7	6.5	22.14	143.91	1	22.14	22.14	22.14	22.14	0.00
7 - 8	7.5	6.24	46.80	2	12.48	24.96	49.92	99.84	6.24
8 - 9	8.5	3.40	28.90	3	10.20	30.60	91.80	275.40	54.40
$\bar{9}$		2.30	21.85	4	9.20	36.80	147.20	588.80	186.30
Total	Σ	100	560.19		10.21	186.39	147.55	1483.23	2070.53
moments around the arbitrary origin					n_1 = 0.102	n_2 = 1.864	n_3 = 1.476	n_4 = 14.832	

m = midpoint of each class   f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 5.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 5.60$ $m_1 = \bar{X} = X_o + cn_1 = 5.602$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 1.8536$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.9077$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 14.3458$ $\sigma_\phi = \sqrt{\sigma^2} = 1.3614$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3597$ $SK = \frac{\sqrt{b_1}}{2} = 0.1798$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.1763$ $K = b_2 - 3 = 1.1763$

Summary: $\bar{X} = 5.602$ $M_\phi = 5.6$ $\sigma_\phi = 1.3614$ SK = 0.1798

$\sqrt{b_1} = 0.3597$ $b_2 = 4.1763$ K = 1.1763

Table 49b

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-27B2 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-8	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-7	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
0 - 1	0.5	0.00	0.00	-5	0.00	0.00	0.00	0.00	0.00
1 - 2	1.5	0.41	0.61	-4	-1.64	6.56	-26.24	104.96	256.25
2 - 3	2.5	1.44	3.60	-3	-4.32	12.96	-38.88	116.64	368.64
3 - 4	3.5	4.31	15.08	-2	-8.62	17.24	-34.48	68.96	349.11
4 - 5	4.5	17.96	80.82	-1	-17.96	17.96	-17.96	17.96	287.36
5 - 6	X_0=5.5	18.45	101.47	0	0.00	0.00	0.00	0.00	18.45
6 - 7	6.5	12.30	79.95	1	12.30	12.30	12.30	12.30	0.00
7 - 8	7.5	16.40	123.00	2	32.80	65.60	131.20	262.40	16.40
8 - 9	8.5	10.25	87.12	3	30.75	92.25	276.75	830.25	164.00
$\bar{9}$		18.48	175.56	4	73.92	295.68	1182.72	4730.88	1496.88
Total	Σ	100	667.21		117.23	520.55	1485.41	6144.35	2957.09
moments around the arbitrary origin					n_1 = 1.172	n_2 = 5.206	n_3 = 14.854	n_4 = 61.444	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 5.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 6.67$ $m_1 = X = X_o + cn_1 = 6.672$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.8325$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.2308$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 29.0516$ $\sigma_\phi = \sqrt{\sigma^2} = 1.9576$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0307$ $SK = \frac{\sqrt{b_1}}{2} = -0.0153$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 1.9782$ $K = b_2 - 3 = -1.0218$

Summary: $\overline{X} = 6.672$ $M_\phi = 6.67$ $\sigma_\phi = 1.9576$ SK = -0.0153

$\sqrt{b_1} = -0.0307$ $b_2 = 1.9782$ K = -1.0218

Table 50

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-28 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-7	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}$.5	0.00	0.00	-5	0.00	0.00	0.00	0.00	0.00
0 - 1	0.5	0.19	0.09	-4	-0.76	3.04	-12.16	48.64	118.75
1 - 2	1.5	0.43	0.64	-3	-1.29	3.87	-11.61	34.83	110.08
2 - 3	2.5	1.64	4.10	-2	-3.28	6.56	-13.12	26.24	132.84
3 - 4	3.5	10.28	35.98	-1	-10.28	10.28	-10.28	10.28	164.48
4 - 5	X_0=4.5	32.05	144.22	0	0.00	0.00	0.00	0.00	32.05
5 - 6	5.5	25.98	142.89	1	25.98	25.98	25.98	25.98	0.00
6 - 7	6.5	6.66	43.29	2	13.32	26.64	53.28	06.56	6.66
7 - 8	7.5	6.66	49.95	3	19.98	59.94	179.82	539.46	106.56
8 - 9	8.5	6.66	56.61	4	26.64	106.56	426.24	1704.96	539.46
$\bar{9}$		9.45	89.77	5	47.25	236.25	1181.25	5906.25	2419.20
Total	Σ	100	567.54		117.56	479.12	1819.4	8303.2	3630.18
moments around the arbitrary origin					n_1 = 1.176	n_2 = 4.791	n_3 = 18.194	n_4 = 83.032	

m = midpoint of each class $\quad f$ = frequency $\quad \bar{X}$ = arithmetic mean

X_ϕ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad X_o = 4.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 5.67 \qquad m_1 = X = X_o + cn_1 = 5.676$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.4081 \qquad m_3 = c^3(n_3-3n_2n_1+2n_1^3) = 4.5438$$

$$m_4 = c^4(n_4-4n_3n_1+6n_1^2n_2-3n_1^4) = 31.4631 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.8461$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.7222 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.3611$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.7089 \qquad K = b_2 - 3 = -0.2911$$

Summary: $\bar{X} = 5.676$ $\quad M_\phi = 5.67$ $\quad \sigma_\phi = 1.8461$ $\quad SK = 0.3611$

$\sqrt{b_1} = 0.7222$ $\quad b_2 = 2.7089$ $\quad K = -0.2911$

Table 51

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-29 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$		0.00	0.00	-7	0.00	0.00	0.00	0.00	0.00
$\overline{2}$ - $\overline{1}$	$\overline{1}.5$	0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
$\overline{1}$ - 0	$\overline{0}.5$	0.44	-0.22	-5	-2.20	11.00	-55.00	275.00	570.24
0 - 1	0.5	1.54	0.77	-4	-6.16	24.64	-98.56	394.24	962.50
1 - 2	1.5	2.37	3.55	-3	-7.11	21.33	-63.99	191.97	606.72
2 - 3	2.5	6.91	17.27	-2	-13.82	27.64	-55.28	110.56	559.71
3 - 4	3.5	20.18	70.63	-1	-20.18	20.18	-20.18	20.18	322.88
4 - 5	X_o=4.5	23.86	107.37	0	0.00	0.00	0.00	0.00	23.86
5 - 6	5.5	14.14	77.77	1	14.14	14.14	14.14	14.14	0.00
6 - 7	6.5	3.80	24.70	2	7.60	15.20	30.40	60.80	3.80
7 - 8	7.5	5.98	44.85	3	17.94	53.82	161.46	484.38	95.68
8 - 9	8.5	8.16	69.36	4	32.64	130.56	522.24	2088.96	660.96
$\overline{9}$		12.62	119.89	5	63.10	315.50	1577.50	7887.50	3230.72
Total	Σ	100	535.94		85.95	634.01	2012.73	11527.73	7037.07
moments around the arbitrary origin					n_1 = 0.859	n_2 = 6.34	n_3 = 20.127	n_4 = 115.277	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = 4.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 5.35$

$m_1 = X = X_o + cn_1 = 5.359$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.6022$

$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 5.0563$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 72.5537$

$\sigma_\phi = \sqrt{\sigma^2} = 2.3668$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3813$

$SK = \frac{\sqrt{b_1}}{2} = 0.1906$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.3121$

$K = b_2 - 3 = -0.6879$

Summary: $\bar{X} = 5.359$ $M_\phi = 5.35$ $\sigma_\phi = 2.3668$ $SK = 0.1906$

$\sqrt{b_1} = 0.3813$ $b_2 = 2.3121$ $K = -0.6879$

Table 52

Computation of Statistics from the first moments of a frequency distribution of a Sample No. A-30 from Pediment A at Khashm Qraydān area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-12	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-11	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	1.04	-0.52	-10	-10.40	104.00	-1040.00	10400.0	15226.64
0 - 1	0.5	2.47	1.23	-9	-22.23	200.07	-1800.63	16205.67	24700.00
1 - 2	1.5	2.19	3.28	-8	-17.52	140.16	-1121.28	8970.24	14368.59
2 - 3	2.5	5.70	14.25	-7	-39.90	279.30	-1955.10	13685.70	23347.20
3 - 4	3.5	14.20	49.70	-6	-85.20	511.20	-3067.20	18403.20	34094.20
4 - 5	4.5	15.90	71.55	-5	-79.50	397.50	-1987.50	9937.50	20606.40
5 - 6	5.5	8.85	48.67	-4	-35.40	141.60	-566.40	2265.60	5531.25
6 - 7	6.5	5.31	34.51	-3	-15.93	47.79	-143.37	430.11	1359.36
7 - 8	7.5	10.62	79.65	-2	-21.24	42.48	-84.96	169.92	860.22
8 - 9	8.5	9.44	80.24	-1	-9.44	9.44	-9.44	9.44	151.04
$\bar{9}$	X_o=	24.28	230.66	0	0.00	0.00	0.00	0.00	24.28
Total	Σ	100	613.22		-336.76	1873.54	-11775.88	80477.38	140269.18
moments around the arbitrary origin					n_1 = -3.368	n_2 = 18.735	n_3 = -117.759	n_4 = 804.774	

m = midpoint of each class   f = frequency $\bar{X}$ = aritlmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f}$ $n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f}$ $n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f}$ $n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 9.5$

$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 6.13$ $m_1 = X = X_o + cn_1 = 6.132$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.3916$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -4.8696$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 107.4182$ $\sigma_\phi = \sqrt{\sigma^2} = 2.7187$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.2423$ $SK = \frac{\sqrt{b_1}}{2} = -0.1211$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 1.9662$ $K = b_2 - 3 = -1.0338$

Summary: $\bar{X} = 6.132$ $M_\phi = 6.13$ $\sigma_\phi = 2.7187$ $SK = -0.1211$

$\sqrt{b_1} = -0.2423$ $b_2 = 1.9662$ $K = -1.0338$

Table 53

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-1A from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		3.27	-8.17	-6	-19.62	117.72	-706.32	4237.92	7851.27
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	5.63	-8.44	-5	-28.15	140.75	-703.75	3518.75	7296.48
$\bar{1}$ - 0	$\bar{0}.5$	6.91	-3.45	-4	-27.64	110.56	-442.24	1768.96	4318.75
0 - 1	0.5	7.77	3.88	-3	-23.31	69.93	-209.79	629.37	1989.12
1 - 2	1.5	10.50	15.75	-2	-21.00	42.00	-84.00	168.00	850.50
2 - 3	2.5	20.66	51.65	-1	-20.66	20.66	-20.66	20.66	330.56
3 - 4	X_o=3.5	28.78	100.73	0	0.00	0.00	0.00	0.00	28.78
4 - 5	4.5	7.96	35.82	1	7.96	7.96	7.96	7.96	0.00
5 - 6	5.5	3.82	21.01	2	7.64	15.28	30.56	61.12	3.82
6 - 7	6.5	1.27	8.25	3	3.81	11.43	34.29	102.87	20.32
7 - 8	7.5	1.27	9.52	4	5.08	20.32	81.28	325.12	102.87
8 - 9	8.5	0.84	7.14	5	4.20	21.00	105.00	525.00	215.04
$\bar{9}$		1.32	12.54	6	7.92	47.52	285.12	1710.72	825.00
Total	Σ	100	246.23		-103.77	625.13	-1622.55	13076.45	23007.51
moments around the arbitrary origin					n_1 = -1.038	n_2 = 6.251	n_3 = -16.226	n_4 = 130.765	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \dfrac{\Sigma\, fd}{\Sigma\, f}$ $n_2 = \dfrac{\Sigma\, fd^2}{\Sigma\, f}$ $n_3 = \dfrac{\Sigma\, fd^3}{\Sigma\, f}$ $n_4 = \dfrac{\Sigma\, fd^4}{\Sigma\, f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = 3.5$

$M_\phi = \dfrac{\Sigma\, fm}{\Sigma\, f} = 2.46$

$m_1 = X = X_o + cn_1 = 2.462$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.1736$

$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 1.0030$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 100.3215$

$\sigma_\phi = \sqrt{\sigma^2} = 2.2745$

$\sqrt{b_1} = \dfrac{m_3}{\sigma_\phi^3} = 0.0852$

$SK = \dfrac{\sqrt{b_1}}{2} = 0.0426$

$b_2 = \dfrac{m_4}{\sigma_\phi^4} = 3.7485$

$K = b_2 - 3 = 0.7485$

Summary: $\overline{X} = 2.462$ $M_\phi = 2.46$ $\sigma_\phi = 2.2745$ $SK = 0.0426$

$\sqrt{b_1} = 0.0852$ $b_2 = 3.7485$ $K = 0.7485$

Table 54

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-1B from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		18.23	-45.57	-1	-18.23	18.23	-18.23	18.23	291.68
$\bar{2} - \bar{1}$	$X_o=\bar{1}.5$	26.78	-40.17	0	0.00	0.00	0.00	0.00	26.78
$\bar{1} - 0$	$\bar{0}.5$	17.62	-8.81	1	17.62	17.62	17.62	17.62	0.00
0 - 1	0.5	12.88	6.44	2	25.76	51.52	103.04	206.08	12.88
1 - 2	1.5	9.16	13.74	3	27.48	82.44	247.32	741.96	146.56
2 - 3	2.5	6.40	16.00	4	25.60	102.40	409.60	1638.40	518.40
3 - 4	3.5	5.89	20.61	5	29.45	147.25	736.25	3681.25	1507.84
4 - 5	4.5	1.52	6.84	6	9.12	54.72	328.32	1969.92	950.00
5 - 6	5.5	0.74	4.07	7	5.18	36.26	253.82	1776.74	959.04
6 - 7	6.5	0.24	1.56	8	1.92	15.36	122.88	983.04	576.24
7 - 8	7.5	0.24	1.80	9	2.16	19.44	174.96	1574.64	983.04
8 - 9	8.5	0.30	2.55	10	3.00	30.00	300.00	3000.00	1968.30
$\bar{9}$		0.00	0.00	11	0.00	0.00	0.00	0.00	0.00
Total	$\sum$	100	-22.08		129.06	575.24	2675.58	15607.88	7940.76
moments around the arbitrary origin					$n_1 =$ 1.291	$n_2 =$ 5.752	$n_3 =$ 26.756	$n_4 =$ 156.079	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $\quad$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $\quad$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $\quad$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = -1.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = -0.22 \qquad m_1 = X = X_o + cn_1 = -0.209$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.0854 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 8.7816$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 67.0962 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.0212$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 1.0635 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.5317$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.0203 \qquad K = b_2 - 3 = 1.0203$$

Summary: $\bar{X} = -0.209$ $\quad$ $M_\phi = -0.22$ $\quad$ $\sigma_\phi = 2.0212$ $\quad$ SK = 0.5317

$\sqrt{b_1} = 1.0635$ $\quad$ $b_2 = 4.0203$ $\quad$ K = 1.0203

Table 55

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-2 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$	$\bar{X}_o$=2.5	26.05	-65.12	0	0.00	0.00	0.00	0.00	26.05
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	4.76	-7.14	1	4.76	4.76	4.76	4.76	0.00
$\bar{1}$ - 0	$\bar{0}$.5	7.60	-3.80	2	15.20	30.40	60.80	121.60	7.60
0 - 1	0.5	4.92	2.46	3	14.76	44.28	132.84	398.52	78.72
1 - 2	1.5	5.79	8.68	4	23.16	92.64	370.56	1482.24	468.99
2 - 3	2.5	15.03	37.55	5	75.15	375.75	1878.75	9393.75	3847.68
3 - 4	3.5	25.66	89.81	6	153.96	923.76	5542.56	33255.36	16037.50
4 - 5	4.5	6.59	29.65	7	46.13	322.91	2260.37	15822.59	8540.64
5 - 6	5.5	1.73	9.51	8	13.84	110.72	885.76	7086.08	4153.73
6 - 7	6.5	0.43	2.79	9	3.87	34.83	313.47	2821.23	1761.28
7 - 8	7.5	0.86	6.45	10	8.60	86.00	860.00	8600.00	5642.46
8 - 9	8.5	0.58	4.93	11	6.38	70.18	771.98	8491.78	5800.00
$\bar{9}$		0.00	0.00	12	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	115.77		365.81	2096.23	13081.85	87477.91	46364.65
moments around the arbitrary origin					n_1 = 3.658	n_2 = 20.962	n_3 = 130.819	n_4 = 874.779	

m = midpoint of each class $\quad f$ = frequency $\quad \overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad K$ = kurtosis $\quad \overline{X}_o = -2.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.157 \qquad m_1 = X = X_o + cn_1 = 1.158$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.5811 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -1.3233$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 106.4303 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.7533$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0634 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.0317$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 1.852 \qquad K = b_2 - 3 = -1.148$$

Summary: $\overline{X} = 1.158 \quad M_\phi = 1.157 \quad \sigma_\phi = 2.7533 \quad SK = -0.0317$

$\sqrt{b_1} = -0.0634 \quad b_2 = 1.852 \quad K = -1.148$

Table 56

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-3 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		13.43	-33.57	-6	-80.58	483.48	-2900.88	17405.28	32245.43
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	3.37	-5.05	-5	-16.85	84.25	-421.25	2106.25	4367.52
$\bar{1}$ - 0	$\bar{0}$.5	7.51	-3.75	-4	-30.04	120.16	-480.64	1922.56	4693.75
0 - 1	0.5	5.73	2.86	-3	-17.19	51.57	-154.71	464.13	1466.88
1 - 2	1.5	6.31	9.46	-2	-12.62	25.24	-50.48	100.96	511.11
2 - 3	2.5	16.58	41.45	-1	-16.58	16.58	-16.58	16.58	265.28
3 - 4	X_o=3.5	31.89	111.61	0	0.00	0.00	0.00	0.00	31.89
4 - 5	4.5	7.62	34.29	1	7.62	7.62	7.62	7.62	0.00
5 - 6	5.5	2.47	13.58	2	4.94	9.88	19.76	39.52	2.47
6 - 7	6.5	1.05	6.82	3	3.15	9.45	28.35	85.05	16.80
7 - 8	7.5	1.41	10.57	4	5.64	22.56	90.24	360.96	114.21
8 - 9	8.5	1.05	8.92	5	5.25	26.25	131.25	656.25	268.80
$\bar{9}$		1.58	15.01	6	9.48	56.88	341.28	2047.68	987.50
Total	Σ	100	212.20		-137.78	913.92	-3406.04	25212.84	44971.64
moments around the arbitrary origin					n_1 = -1.378	n_2 = 9.139	n_3 = -34.06	n_4 = 252.128	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $X_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.12 \qquad m_1 = X = X_o + cn_1 = 2.122$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.2402 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -1.5124$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 157.6915 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.6907$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0776 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.0388$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.0085 \qquad K = b_2 - 3 = 0.0085$$

Summary: $\quad$ $\overline{X} = 2.122$ $\quad$ $M_\phi = 2.12$ $\quad$ $\sigma_\phi = 2.6907$ $\quad$ SK = $-0.-388$

$\sqrt{b_1} = -0.0776$ $\quad$ $b_2 = 3.0085$ $\quad$ $K = 0.0085$

Table 57

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-4 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		13.42	-33.55	-6	-80.52	483.12	-2898.72	17392.32	32221.42
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	5.38	-8.07	-5	-26.90	134.50	-672.50	3362.50	6972.48
$\bar{1}$ - 0	$\bar{0}$.5	5.17	-2.58	-4	-20.68	82.72	-330.88	1323.52	3231.25
0 - 1	0.5	5.22	2.61	-3	-15.66	46.98	-140.94	422.82	1336.32
1 - 2	1.5	7.17	10.75	-2	-14.34	28.68	-57.36	114.72	580.77
2 - 3	2.5	16.35	40.87	-1	-16.35	16.35	-16.35	16.35	261.60
3 - 4	X_o=3.5	29.66	103.81	0	0.00	0.00	0.00	0.00	29.66
4 - 5	4.5	6.89	31.00	1	6.89	6.89	6.89	6.89	0.00
5 - 6	5.5	0.82	4.51	2	1.64	3.28	6.56	13.12	0.82
6 - 7	6.5	0.82	5.33	3	2.46	7.38	22.14	66.42	13.12
7 - 8	7.5	2.05	15.37	4	8.12	32.48	129.92	519.68	164.43
8 - 9	8.5	0.82	6.97	5	4.10	20.50	102.50	512.50	209.92
$\bar{9}$		6.23	59.18	6	37.38	224.28	1345.68	8074.08	3893.75
Total	Σ	100	236.20		-113.86	1087.16	-2503.06	31824.92	48915.54
moments around the arbitrary origin					n_1 = -1.139	n_2 = 10.872	n_3 = -25.031	n_4 = 318.249	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals.

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $X_o = 3.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 2.36 \qquad m_1 = X = X_o + cn_1 = 2.361$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 9.5747 \qquad m_3 = c^3(n_3 - 3n_2 n_1 + 2n_1^3) = 9.1634$$

$$m_4 = c^4(n_4 - 4n_3 n_1 + 6n_1^2 - 3n_1^4) = 283.7845 \qquad \sigma_\phi = \sqrt{\sigma^2} = 3.0943$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3092 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.1546$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.0956 \qquad K = b_2 - 3 = 0.0956$$

Summary: $\overline{X} = 2.361$ $\quad$ $M_\phi = 2.36$ $\quad$ $\sigma_\phi = 3.0943$ $\quad$ SK = 0.1546

$\sqrt{b_1} = 0.3092$ $\quad$ $b_2 = 3.0956$ $\quad$ K = 0.0956

Table 58

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-5 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		20.03	-50.07	-6	-120.18	721.08	-4326.48	25958.88	48092.03
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	2.91	-4.36	-5	-14.55	72.75	-363.75	1818.75	3771.36
$\bar{1}$ - 0	$\bar{0}.5$	4.27	-2.13	-4	-17.08	68.32	-273.28	1093.12	2668.78
0 - 1	0.5	4.51	2.25	-3	-13.53	40.59	-121.77	365.31	1154.56
1 - 2	1.5	6.32	9.48	-2	-12.64	25.28	-50.56	101.12	511.92
2 - 3	2.5	15.62	39.05	-1	-15.62	15.62	-15.62	15.62	249.92
3 - 4	X_o=3.5	28.32	99.12	0	0.00	0.00	0.00	0.00	28.32
4 - 5	4.5	9.94	44.73	1	9.94	9.94	9.94	9.94	0.00
5 - 6	5.5	1.99	10.94	2	3.98	7.96	15.92	31.34	1.99
6 - 7	6.5	1.19	7.73	3	3.57	10.71	32.13	96.39	19.04
7 - 8	7.5	1.59	11.92	4	6.36	25.44	101.76	407.04	128.79
8 - 9	8.5	0.79	6.71	5	3.95	19.75	98.75	493.75	202.24
$\bar{9}$		2.52	23.94	6	15.12	90.72	544.32	3265.92	1575.00
Total	Σ	100	199.31		-150.68	1108.16	-4348.64	33648.18	58403.95
moments around the arbitrary origin					n_1 = -1.507	n_2 = 11.082	n_3 = -43.486	n_4 = 336.482	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $X_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.99 \qquad m_1 = X = X_o + cn_1 = 1.993$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 8.811 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.2289$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 209.8795 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.9633$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0087 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.0043$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.7035 \qquad K = b_2 - 3 = -0.2965$$

Summary: $\bar{X} = 1.993$ $\quad$ $M_\phi = 1.99$ $\quad$ $\sigma_\phi = 2.9633$ $\quad$ $SK = -0.0043$

$\sqrt{b_1} = -0.0087$ $\quad$ $b_2 = 2.7035$ $\quad$ $K = -0.2965$

Table 59

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-6 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$	$X_o=\overline{2}.5$	44.51	-111.27	0	0.00	0.00	0.00	0.00	44.51
$\overline{2}$ - $\overline{1}$	$\overline{1}.5$	8.86	-13.29	1	8.86	8.86	8.86	8.86	0.00
$\overline{1}$ - 0	$\overline{0}.5$	5.40	-2.70	2	10.80	21.60	43.20	86.40	5.40
0 - 1	0.5	4.13	2.06	3	12.39	37.17	111.51	334.53	66.08
1 - 2	1.5	5.38	8.38	4	21.52	86.08	344.32	1377.28	435.78
2 - 3	2.5	11.36	28.40	5	56.80	284.00	1420.00	7100.00	2908.16
3 - 4	3.5	16.17	56.59	6	97.02	582.12	3492.72	20956.32	10106.25
4 - 5	4.5	3.43	15.43	7	24.01	168.07	1176.49	8235.43	4445.28
5 - 6	5.5	0.76	4.18	8	6.08	48.64	389.12	3112.96	1824.76
6 - 7	6.5	0.00	0.00	9	0.00	0.00	0.00	0.00	0.00
7 - 8	7.5	0.00	0.00	10	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	11	0.00	0.00	0.00	0.00	0.00
$\overline{9}$		0.00	0.00	12	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	-13.63		237.48	1236.54	6986.22	41211.78	19836.22
moments around the arbitrary origin					n_1 = 2.375	n_2 = 12.365	n_3 = 69.862	n_4 = 412.118	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $X_o = -2.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = -0.13 \qquad m_1 = X = X_o + cn_1 = -0.125$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.7244 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 8.5542$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 71.4559 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.5931$$

$$b_1 = \frac{m_3}{\sigma_\phi^3} = 0.4906 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.2453$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 1.5804 \qquad K = b_2 - 3 = -1.4196$$

Summary: $\overline{X} = -0.125$ $\quad$ $M_\phi = -0.13$ $\quad$ $\sigma_\phi = 2.5931$ $\quad$ SK = 0.2453

$\sqrt{b_1} = 0.4906$ $\quad$ $b_2 = 1.5804$ $\quad$ K = -1.4196

Table 60

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-7 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$	X_o=	27.09	-67.72	0	0.00	0.00	0.00	0.00	27.09
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	7.86	-11.79	1	7.86	7.86	7.86	7.86	0.00
$\bar{1}$ - 0	$\bar{0}$.5	9.01	-4.50	2	18.02	36.04	72.08	144.16	9.01
0 - 1	0.5	9.02	4.51	3	27.06	81.18	243.54	730.62	144.32
1 - 2	1.5	7.06	10.59	4	28.24	112.96	451.84	1807.36	574.86
2 - 3	2.5	13.72	34.30	5	68.60	343.00	1715.00	8575.00	3512.32
3 - 4	3.5	16.89	59.11	6	101.34	608.04	3648.24	21889.44	10556.25
4 - 5	4.5	6.07	27.31	7	42.49	297.43	2082.01	14574.07	7866.72
5 - 6	5.5	0.79	4.34	8	6.32	50.56	404.48	3235.84	1896.79
6 - 7	6.5	1.19	7.73	9	10.71	96.39	867.51	7807.59	4874.24
7 - 8	7.5	0.39	2.92	10	3.90	39.00	390.00	3900.00	2558.79
8 - 9	8.5	0.39	3.31	11	4.29	47.19	519.09	5709.99	3900.00
$\bar{9}$		0.52	4.94	12	6.24	74.88	898.56	10782.72	7613.32
Total	Σ	100	75.05		325.07	1794.53	11300.21	79164.38	43533.71
moments around the arbitrary origin					n_1 = 3.251	n_2 = 17.945	n_3 = 113.002	n_4 = 791.644	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = -2.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.75$$

$$m_1 = X = X_o + cn_1 = 0.751$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.376$$

$$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 6.7041$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 125.0191$$

$$\sigma_\phi = \sqrt{\sigma^2} = 2.7158$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3346$$

$$SK = \frac{\sqrt{b_1}}{2} = 0.1673$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.2982$$

$$K = b_2 - 3 = -0.7018$$

Summary: $\overline{X} = 0.751$ $M_\phi = 0.75$ $\sigma_\phi = 2.7158$ $SK = 0.1673$

$\sqrt{b_1} = 0.3346$ $b_2 = 2.2982$ $K = -0.7018$

Table 61

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-8 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$	X_o=	26.90	-67.25	0	0.00	0.00	0.00	0.00	26.90
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	6.79	-10.18	1	6.79	6.79	6.79	6.79	0.00
$\bar{1}$ - 0	$\bar{0}.5$	9.85	-4.92	2	19.70	39.40	78.80	157.60	9.85
0 - 1	0.5	10.38	5.19	3	31.14	93.42	280.26	840.78	166.08
1 - 2	1.5	6.31	9.46	4	25.24	100.96	403.84	1615.36	511.11
2 - 3	2.5	12.28	30.70	5	61.40	307.00	1535.00	7675.00	3143.68
3 - 4	3.5	17.98	62.93	6	107.88	647.28	3883.68	23302.08	11237.50
4 - 5	4.5	5.89	26.50	7	41.23	288.61	2020.27	14141.89	7633.44
5 - 6	5.5	0.36	1.98	8	2.88	23.04	184.32	1474.56	864.36
6 - 7	6.5	0.73	4.74	9	6.57	59.13	532.17	4789.53	2990.08
7 - 8	7.5	1.09	8.17	10	10.90	109.00	1090.00	10900.00	7151.49
8 - 9	8.5	0.36	3.06	11	3.96	43.56	479.16	5270.76	3600.00
$\bar{9}$		1.08	10.26	12	12.96	155.52	1866.24	22394.88	15812.28
Total	Σ	100	80.63		330.65	1873.71	12360.53	92569.23	53146.77
moments around the arbitrary origin					n_1 = 3.307	n_2 = 18.737	n_3 = 123.605	n_4 = 925.692	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \dfrac{\Sigma\, fd}{\Sigma\, f}$ $n_2 = \dfrac{\Sigma\, fd^2}{\Sigma\, f}$ $n_3 = \dfrac{\Sigma\, fd^3}{\Sigma\, f}$ $n_4 = \dfrac{\Sigma\, fd^4}{\Sigma\, f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = -2.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 0.80 \qquad m_1 = X = X_o + cn_1 = 0.807$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.8008 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 10.0473$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 161.3118 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.7929$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.4612 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.2306$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.6512 \qquad K = b_2 - 3 = -0.3488$$

Summary: $\overline{X} = 0.807$ $M_\phi = 0.80$ $\sigma_\phi = 2.7929$ $SK = 0.2306$

$\sqrt{b_1} = 0.4612$ $b_2 = 2.6512$ $K = -0.3488$

Table 62

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-9 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$	X_o=-2.5	37.48	-93.70	0	0.00	0.00	0.00	0.00	37.48
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	10.42	-15.63	1	10.42	10.42	10.42	10.42	0.00
$\bar{1}$ - 0	$\bar{0}$.5	11.60	-5.80	2	23.20	46.40	92.80	185.60	11.60
0 - 1	0.5	7.90	3.95	3	23.70	71.10	213.30	639.90	126.40
1 - 2	1.5	4.69	7.03	4	18.76	75.04	300.16	1200.64	379.89
2 - 3	2.5	9.08	22.70	5	45.40	227.00	1135.00	5675.00	2324.48
3 - 4	3.5	12.32	43.12	6	73.92	443.52	2661.12	15966.72	7700.00
4 - 5	4.5	2.04	9.18	7	14.28	99.96	699.72	4898.04	2643.84
5 - 6	5.5	0.74	4.07	8	5.92	47.36	378.88	3031.04	1776.74
6 - 7	6.5	1.11	7.21	9	9.99	89.91	809.19	7282.71	4546,56
7 - 8	7.5	0.74	5.55	10	7.40	74.0	740.0	7400.0	4855.14
8 - 9	8.5	0.37	3.14	11	4.07	44.77	492.47	5417.17	3700.0
$\bar{9}$		1.51	14.34	12	18.12	217.44	2609.28	31311.36	22107.91
Total	Σ	100	5.16		255.18	1446.92	10142.34	83018.6	50210.04
moments around the arbitrary origin					n_1 = 2.552	n_2 = 14.469	n_3 = 101.423	n_4 = 830.186	

m = midpoint of each class   f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma\, fd}{\Sigma\, f}$ $n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f}$ $n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f}$ $n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = -2.5$

$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 0.05$

$m_1 = X = X_o + cn_1 = 0.052$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.9563$

$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 23.8892$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 233.0080$

$\sigma_\phi = \sqrt{\sigma^2} = 2.8206$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 1.0645$

$SK = \frac{\sqrt{b_1}}{2} = 0.5322$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.6813$

$K = b_2 - 3 = 0.6813$

Summary: $\bar{X} = 0.052$ $M_\phi = 0.05$ $\sigma_\phi = 2.8206$ $SK = 0.5322$

$\sqrt{b_1} = 1.0645$ $b_2 = 3.6813$ $K = 0.6813$

Table 63

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B -10 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		8.13		-6	-48.78	292.68	-1756.08	10536.48	19520.13
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	8.91		-5	-44.55	222.75	-1113.75	5568.75	11547.36
$\bar{1}$ - 0	$\bar{0}.5$	14.41		-4	-57.64	230.56	-922.24	3688.96	9006.25
0 - 1	0.5	13.94		-3	-41.82	125.46	-376.38	1129.14	3568.64
1 - 2	1.5	7.11		-2	-14.22	28.44	-56.88	113.76	575.91
2 - 3	2.5	15.51		-1	-15.51	15.51	-15.51	15.51	248.16
3 - 4	3.5	20.04		0	0.00	0.00	0.00	0.00	20.04
4 - 5	4.5	4.37		1	4.37	4.37	4.37	4.37	0.00
5 - 6	5.5	3.09		2	6.18	12.36	24.72	49.44	3.09
6 - 7	6.5	1.24		3	3.72	11.16	33.48	100.44	19.84
7 - 8	7.5	0.71		4	2.84	11.36	45.44	181.76	57.51
8 - 9	8.5	2.54		5	12.70	63.50	317.50	1587.50	650.24
$\bar{9}$		0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-192.71	1018.15	-3815.33	22976.11	45217.17
moments around the arbitrary origin					$n_1 =$ -1.927	$n_2 =$ 10.182	$n_3 =$ -38.153	$n_4 =$ 229.761	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = 3.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 1.57 \qquad m_1 = X = X_o + cn_1 = 1.573$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.4687 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 6.3981$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 121.1648 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.5433$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3889 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.1944$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.8959 \qquad K = b_2 - 3 = -0.1041$$

Summary: $\overline{X} = 1.573$ $M_\phi = 1.57$ $\sigma_\phi = 2.5433$ SK = 0.1944

$\sqrt{b_1} = 0.3889$ $b_2 = 2.8959$ K = -0.1041

Table 64

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-12 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		10.71		-6	-64.26	385.56	-2313.36	13880.16	25714.71
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	10.06		-5	-50.30	251.50	1257.50	6287.50	13037.76
$\bar{1}$ - 0	$\bar{0}.5$	9.79		-4	-39.16	156.64	-626.56	2506.24	6118.75
0 - 1	0.5	13.20		-3	-39.60	118.80	-356.40	1069.20	3379.20
1 - 2	1.5	8.93		-2	-17.86	35.72	-71.44	142.88	723.33
2 - 3	2.5	16.75		-1	-16.75	16.75	-16.75	16.75	268.00
3 - 4	$\bar{X}_o$=3.5	20.06		0	0.00	0.00	0.00	0.00	20.06
4 - 5	4.5	5.46		1	5.46	5.46	5.46	5.46	0.00
5 - 6	5.5	2.83		2	5.66	11.32	22.64	45.28	2.83
6 - 7	6.5	1.11		3	3.33	9.99	29.97	89.91	17.76
7 - 8	7.5	0.42		4	1.68	6.72	26.88	107.52	34.02
8 - 9	8.5	0.68		5	3.40	17.0	85.0	425.0	174.08
$\bar{9}$		0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-208.4	1015.46	-4472.04	24575.90	49508.5
moments around the arbitrary origin					n_1 = -2.084	n_2 = 10.155	n_3 = -44.72	n_4 = 245.759	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.41 \qquad m_1 = X = X_o + cn_1 = 1.416$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.812 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.6674$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 81.0066 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.4108$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0476 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.0238$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.3981 \qquad K = b_2 - 3 = -0.6019$$

Summary: $\bar{X} = 1.416$ $M_\phi = 1.41$ $\sigma_\phi = 2.4108$ $SK = 0.0238$

$\sqrt{b_1} = 0.0476$ $b_2 = 2.3981$ $K = -0.6019$

Table 65

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-13 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		9.83		-6	-58.98	353.88	-2123.28	12739.68	23601.83
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	11.28		-5	-56.40	282.0	-1410.0	7050.0	14618.88
$\bar{1}$ - 0	$\bar{0}.5$	8.05		-4	-32.20	128.80	-515.20	2060.80	5031.25
0 - 1	0.5	11.71		-3	-35.13	105.39	-316.17	948.51	2997.76
1 - 2	1.5	8.81		-2	-17.62	35.24	-70.48	140.96	713.61
2 - 3	2.5	18.18		-1	-18.18	18.18	-18.18	18.18	290.88
3 - 4	$\bar{X}_0$=3.5	21.05		0	0.00	0.00	0.00	0.00	21.05
4 - 5	4.5	6.51		1	6.51	6.51	6.51	6.51	0.00
5 - 6	5.5	2.65		2	5.30	10.60	21.20	42.40	2.65
6 - 7	6.5	0.67		3	2.01	6.03	18.09	54.27	10.72
7 - 8	7.5	0.64		4	2.56	10.24	40.96	163.84	51.84
8 - 9	8.5	0.62		5	3.10	15.50	77.50	387.50	158.72
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	
Total	Σ	100			-199,03	972.37	-4289.05	23612.65	47499.19
moments around the arbitrary origin					n_1 = -1.99	n_2 = 9.724	n_3 = -42.891	n_4 = 236.127	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.51 \qquad m_1 = X = X_o + cn_1 = 1.51$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.7639 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.5278$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 78.7164 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.4008$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0381 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.019$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.3694 \qquad K = b_2 - 3 = -0.6306$$

Summary: $\bar{X} = 1.51$ $M_\phi = 1.51$ $\sigma_\phi = 2.4008$ SK = -0.019

$\sqrt{b_1} = -0.0381$ $b_2 = 2.3694$ K = -0.6306

Table 66

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-14 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		8.64		-5	-43.20	216.0	-1080.0	5400.0	11197.44
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	11.37		-4	-45.48	181.92	-727.68	2910.72	7106.25
$\bar{1}$ - 0	$\bar{0}.5$	12.20		-3	-36.60	109.80	-329.40	988.20	3123.20
0 - 1	0.5	16.32		-2	-20.64	41.28	-82.56	165.12	835.92
1 - 2	1.5	9.60		-1	-9.60	9.60	-9.60	9.60	153.60
2 - 3	$\bar{X}_o$=2.5	16.35		0	0.00	0.00	0.00	0.00	16.35
3 - 4	3.5	16.10		1	16.10	16.10	16.10	16.10	0.00
4 - 5	4.5	7.50		2	15.0	30.0	60.0	120.0	7.50
5 - 6	5.5	1.03		3	3.09	9.27	27.81	83.43	16.48
6 - 7	6.5	0.33		4	1.32	5.28	21.12	84.48	26.73
7 - 8	7.5	0.19		5	0.95	4.75	23.75	118.75	48.64
8 - 9	8.5	0.37		6	2.22	13.32	79.92	479.52	231.25
$\bar{9}$		0.00		7	0.00	0.00	0.00	0.00	0.00
Total	$\sum$				-116.84	637.32	-2000.54	10375.92	22763.36
moments around the arbitrary origin					n_1 = -1.168	n_2 = 6.373	n_3 = -20.001	n_4 = 103.759	

m = midpoint of each class $\quad f$ = frequency $\quad \bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \bar{X}_o = 2.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.33 \qquad m_1 = X = X_o + cn_1 = 1.332$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.0088 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.8567$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 56.8959 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.238$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0764 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.0382$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.268 \qquad K = b_2 - 3 = -0.732$$

Summary: $\bar{X} = 1.332$ $\quad M_\phi = 1.33$ $\quad \sigma_\phi = 2.238$ $\quad SK = -0.0382$

$\sqrt{b_1} = -0.0764$ $\quad b_2 = 2.268$ $\quad K = -0.732$

Table 67

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-15 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		15.99		-1	-15.99	15.99	-15.99	15.99	255.84
$\bar{2} - \bar{1}$	$X_o = \bar{1}.5$	18.66		0	0.00	0.00	0.00	0.00	18.66
$\bar{1} - 0$	$\bar{0}.5$	10.86		1	10.68	10,68	10.68	10.68	0.00
0 - 1	0.5	12.12		2	24.24	48.48	96.96	193.92	12.12
1 - 2	1.5	9.40		3	28.20	84.60	253.80	761.40	150.40
2 - 3	2.5	14.04		4	56.16	224.64	898.56	3594.24	1137.24
3 - 4	3.5	11.44		5	57.20	286.00	1430.0	7150.0	2928.64
4 - 5	4.5	3.76		6	22.56	135.36	812.16	4872.96	2350.00
5 - 6	5.5	2.26		7	15.82	110.74	775.18	5426.26	2928.96
6 - 7	6.5	0.68		8	5.44	43.52	348.16	2785.28	1632.68
7 - 8	7.5	0.33		9	2.97	26.73	240.57	2165.13	1351.68
8 - 9	8.5	0.46		10	4.60	46.0	460.0	4600.0	3018.06
$\bar{9}$		0.00		11	0.00	0.00	0.00	0.00	0.00
Total	Σ				211.88	1032.74	5310.08	31575.86	15784.28
moments around the arbitrary origin					$n_1 =$ 2.189	$n_2 =$ 10.327	$n_3 =$ 53.101	$n_4 =$ 315.759	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = -1.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.68 \qquad m_1 = X = X_o + cn_1 = 0.689$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.5353 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 6.2616$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 78.8288 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.3527$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.4808 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.2404$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.5729 \qquad K = b_2 - 3 = -0.4271$$

Summary: $\overline{X} = 0.689$ $M_\phi = 0.68$ $\sigma_\phi = 2.3527$ SK = 0.2404

$\sqrt{b_1} = 0.4808$ $b_2 = 2.5729$ K = -0.4271

Table 68

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-16A from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		3.93		-6	-23.58	141.48	-848.88	5093.28	9435.93
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	9.67		-5	-48.35	241.75	-1208.75	6043.75	12532.32
$\bar{1}$ - 0	$\bar{0}.5$	6.40		-4	-25.60	102.40	-409.60	1638.40	4000.00
0 - 1	0.5	6.40		-3	-19.20	57.60	-172.80	518.40	1638.40
1 - 2	1.5	7.00		-2	-14.00	28.00	-56.00	112.00	567.00
2 - 3	2.5	18.20		-1	-18.20	18.20	-18.20	18.20	291.20
3 - 4	$\bar{X}_o$=3.5	23.27		0	0.00	0.00	0.00	0.00	23.27
4 - 5	4.5	9.82		1	9.82	9.82	9.82	9.82	0.00
5 - 6	5.5	5.71		2	11.42	22.84	45.68	91.36	5.71
6 - 7	6.5	3.43		3	10.29	30.87	92.61	277.83	54.88
7 - 8	7.5	1.67		4	6.68	26.72	106.88	427.52	135.27
8 - 9	8.5	4.50		5	22.50	112.50	562.50	2812.50	1152.00
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-88.22	792.18	-1896.74	17043.06	29853.98
moments around the arbitrary origin					n_1 = -0.882	n_2 = 7.922	n_3 = -18.967	n_4 = 170.431	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.61 \qquad m_1 = X = X_o + cn_1 = 2.618$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.1441 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.6224$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 138.6753 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.6728$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0325 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.0162$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.7173 \qquad K = b_2 - 3 = -0.2827$$

Summary: $\overline{X} = 2.618$ $M_\phi = 2.61$ $\sigma_\phi = 2.6728$ $SK = 0.0162$

$\sqrt{b_1} = 0.0325$ $b_2 = 2.7173$ $K = -0.2827$

Table 69

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B -16B from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		6.68		-6	-40.08	240.48	-1442.88	8657.28	16038.68
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	10.47		-5	-52.35	261.75	-1308.75	6543.75	13569.12
$\bar{1}$ - 0	$\bar{0}$.5	6.81		-4	-27.24	108.96	-435.84	1743.36	4256.25
0 - 1	0.5	6.38		-3	-19.14	57.42	-172.26	516.78	1633.28
1 - 2	1.5	7.24		-2	-14.48	28.96	-57.92	115.84	586.44
2 - 3	2.5	18.26		-1	-18.26	18.26	-18.26	18.26	292.16
3 - 4	X_0=3.5	20.51		0	0.00	0.00	0.00	0.00	20.51
4 - 5	4.5	7.99		1	7.99	7.99	7.99	7.99	0.00
5 - 6	5.5	6.70		2	13.40	26.80	53.60	107.20	6.70
6 - 7	6.5	3.29		3	9.87	29.61	88.83	266.49	52.64
7 - 8	7.5	1.32		4	5.28	21.12	84.48	337.92	106.92
8 - 9	8.5	4.35		5	21.75	108.75	543.75	2718.75	1113.60
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-113.26	910.10	-2657.26	21033.62	37676.30
moments around the arbitrary origin					n_1 = -1.133	n_2 = 9.101	n_3 = -26.573	n_4 = 210.336	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\overline{X}_o = 3.5$

$M_o = \frac{\Sigma fm}{\Sigma f} = 2.36$ $m_1 = X = X_o + cn_1 = 2.367$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.8174$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 1.4526$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 155.0563$ $\sigma_\phi = \sqrt{\sigma^2} = 2.7959$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0664$ $SK = \frac{\sqrt{b_1}}{2} = 0.0332$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.5375$ $K = b_2 - 3 = -0.4625$

Summary: $\overline{X} = 2.367$ $M_\phi = 2.36$ $\sigma_\phi = 2.7959$ $SK = 0.0332$

$\sqrt{b_1} = 0.0664$ $b_2 = 2.5375$ $K = -0.4625$

Table 70

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-17 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		7.14		-6	-42.84	257.04	-1542.24	9253.44	17143.14
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	9.70		-5	-48.50	242.50	-1212.50	6062.50	12571.20
$\bar{1}$ - 0	$\bar{0}$.5	5.76		-4	-23.04	92.16	-368.64	1474.56	3600.00
0 - 1	0.5	6.88		-3	-20.64	61.92	-185.76	557.28	1761.28
1 - 2	1.5	9.83		-2	-19.66	39.32	-78.64	157.28	796.23
2 - 3	2.5	18.83		-1	-18.83	18.83	-18.83	18.83	301.28
3 - 4	$\bar{X}_o$=3.5	24.20		0	0.00	0.00	0.00	0.00	24.20
4 - 5	4.5	7.92		1	7.92	7.92	7.92	7.92	0.00
5 - 6	5.5	3.47		2	6.94	13.88	27.76	55.52	3.47
6 - 7	6.5	2.42		3	7.26	21.78	65.34	196.02	38.72
7 - 8	7.5	1.08		4	4.32	17.28	69.12	276.48	87.48
8 - 9	8.5	2.77		5	13.85	69.25	346.25	1731.25	709.12
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-133.22	841.88	-2890.22	19791.08	37036.12
moments around the arbitrary origin					n_1 = -1.332	n_2 = 8.419	n_3 = -28.902	n_4 = 197.911	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals.

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \quad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \quad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \quad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 3.5$

$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 2.16$ $\qquad$ $m_1 = X = X_o + cn_1 = 2.168$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.6448$ $\qquad$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.0139$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 124.1000$ $\qquad$ $\sigma_\phi = \sqrt{\sigma^2} = 2.5777$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0008$ $\qquad$ $SK = \frac{\sqrt{b_1}}{2} = 0.0004$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.8109$ $\qquad$ $K = b_2 - 3 = -0.1891$

Summary: $\bar{X} = 2.168$ $\quad$ $M_\phi = 2.16$ $\quad$ $\sigma_\phi = 2.5777$ $\quad$ $SK = 0.0004$

$\sqrt{b_1} = 0.0008$ $\quad$ $b_2 = 2.8109$ $\quad$ $K = -0.1891$

Table 71

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-18 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		8.34		-6	-50.04	300.24	-1801.44	10808.64	20024.36
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	10.60		-5	-53.0	265.0	-1325.0	6625.0	13737.60
$\bar{1}$ - 0	$\bar{0}.5$	5.45		-4	-21.80	87.20	-348.80	1395.20	3406.25
0 - 1	0.5	7.53		-3	-22.59	67.77	-203.31	609.93	1927.68
1 - 2	1.5	10.05		-2	-20.10	40.20	-80.40	160.80	814.05
2 - 3	2.5	17.83		-1	-17.83	17.83	-17.83	17.83	285.28
3 - 4	$\bar{X}_0$=3.5	21.83		0	0.00	0.00	0.00	0.00	21.83
4 - 5	4.5	7.55		1	7.55	7.55	7.55	7.55	0.00
5 - 6	5.5	3.43		2	6.94	13.88	27.76	55.52	3.47
6 - 7	6.5	2.74		3	8.22	24.66	73.98	221.94	43.84
7 - 8	7.5	1.20		4	4.80	19.20	76.80	307.20	97.20
8 - 9	8.5	3.45		5	17.11	84.87	420.93	2087.80	848.25
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-140.74	928.4	-2585.76	22297.41	41209.81
moments around the arbitrary origin					n_1 = -1.407	n_2 = 9.284	n_3 = -25.858	n_4 = 222.974	

m = midpoint of each class $\quad f$ = frequency $\quad \bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 2.09 \qquad m_1 = X = X_o + cn_1 = 2.093$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.3044 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 7.7593$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 175.9607 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.7026$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.393 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.1965$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.2983 \qquad K = b_2 - 3 = 0.2983$$

Summary: $\bar{X} = 2.093 \quad M_\phi = 2.09 \quad \sigma_\phi = 2.7026 \quad SK = 0.1965$

$\sqrt{b_1} = 0.393 \quad b_2 = 3.2983 \quad K = 0.2983$

Table 72

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-19 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$		5.29		-6	-31.74	190.44	-1142.64	6855.84	12701.29
$\overline{2}$ - $\overline{1}$	$\overline{1}$.5	7.06		-5	-35.30	176.50	-882.50	4412.50	9149.76
$\overline{1}$ - 0	$\overline{0}$.5	4.58		-4	-18.32	73.28	-293.12	1172.48	2862.50
0 - 1	0.5	6.86		-3	-20.58	61.74	-185.22	555.66	1756.16
1 - 2	1.5	9.47		-2	-18.94	37.88	-75.76	151.52	767.07
2 - 3	2.5	10.01		-1	-19.01	19.01	-19.01	19.01	304.16
3 - 4	$\overline{X}_o$=3.5	23.24		0	0.00	0.00	0.00	0.00	23.24
4 - 5	4.5	9.53		1	9.53	9.53	9.53	9.53	0.00
5 - 6	5.5	6.23		2	12.46	24.92	49.84	99.68	6.23
6 - 7	6.5	3.39		3	10.17	30.51	91.53	274.59	54.24
7 - 8	7.5	1.53		4	6.12	24.48	97.92	391.68	123.93
8 - 9	8.5	3.81		5	19.05	95.25	476.25	2381.25	975.36
$\overline{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-86.56	743.54	-1873.18	16323.74	28723.94
moments around the arbitrary origin					n_1 = -0.866	n_2 = 7.435	n_3 = -18.732	n_4 = 163.237	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\overline{X}_o = 3.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 2.63 \qquad m_1 = X = X_o + cn_1 = 2.634$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.6851 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.7147$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 130.1155 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.5855$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0413 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.206$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.9117 \qquad K = b_2 - 3 = -0.0883$$

Summary: $\overline{X} = 2.634$ $M_\phi = 2.63$ $\sigma_\phi = 2.5855$ $SK = -0.206$

$\sqrt{b_1} = -0.0413$ $b_2 = 2.9117$ $K = -0.0883$

Table 73

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B -20 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		5.12		-6	-30.72	184.32	-1105.92	6635.52	12293.12
$\bar{2} - \bar{1}$	$\bar{1}.5$	5.42		-5	-27.10	135.50	-677.50	3387.50	7024.32
$\bar{1} - 0$	$\bar{0}.5$	4.45		-4	-17.80	71.20	-284.80	1139.20	2781.25
0 - 1	0.5	6.42		-3	-19.26	57.78	-173.34	520.02	1643.52
1 - 2	1.5	8.66		-2	-17.32	34.64	-69.28	138.56	701.46
2 - 3	2.5	18.85		-1	-18.85	18.85	-18.85	18.85	301.60
3 - 4	$\bar{X}_o=3.5$	24.25		0	0.00	0.00	0.00	0.00	24.25
4 - 5	4.5	11.01		1	11.01	11.01	11.01	11.01	0.00
5 - 6	5.5	5.21		2	10.42	20.84	41.68	83.36	5.21
6 - 7	6.5	3.57		3	10.71	32.13	96.39	289.17	57.12
7 - 8	7.5	2.12		4	8.48	33.92	135.68	542.72	171.72
8 - 9	8.5	4.92		5	24.60	123.0	615.0	3075.0	1259.52
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ				-65.83	723.19	-1429.93	15840.91	26263.09
moments around the arbitrary origin					$n_1 =$ -0.658	$n_2 =$ 7.232	$n_3 =$ -14.299	$n_4 =$ 158.409	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = 3.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.84$ $m_1 = X = X_o + cn_1 = 2.842$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.7991$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.5927$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 138.9965$ $\sigma_\phi = \sqrt{\sigma^2} = 2.6075$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.0334$ $SK = \frac{\sqrt{b_1}}{2} = -0.0167$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.0068$ $K = b_2 - 3 = 0.0068$

Summary: $\overline{X} = 2.842$ $M_\phi = 2.84$ $\sigma_\phi = 2.6075$ $SK = -0.0167$

$\sqrt{b_1} = -0.0334$ $b_2 = 3.0068$ $K = 0.0068$

Table 74

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-21 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		29.54		0	0.00	0.00	0.00	0.00	29.54
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	24.86		1	24.86	24.86	24.86	24.86	0.00
$\bar{1}$ - 0	$\bar{0}$.5	10.24		2	20.48	40.96	81.92	163.84	10.24
0 - 1	0.5	4.46		3	13.38	40.14	120.42	361.26	71.36
1 - 2	1.5	3.31		4	13.24	52.96	211.84	847.36	268.11
2 - 3	2.5	6.75		5	33.75	168.75	843.75	4218.75	1728.00
3 - 4	3.5	10.47		6	62.82	376.92	2261.52	13569.12	6543.75
4 - 5	4.5	4.43		7	31.01	217.07	1519.49	10636.43	5741.28
5 - 6	5.5	3.07		8	24.56	196.48	1571.84	12574.72	7371.07
6 - 7	6.5	1.36		9	12.24	110.16	991.44	8922.96	5570.56
7 - 8	7.5	0.58		10	5.80	58.0	580.0	5800.0	3805.38
8 - 9	8.5	0.93		11	10.23	112.53	1237.83	13616.13	9300.0
$\bar{9}$		0.00		12	0.00	0.00	0.00	0.00	0.00
Total	Σ -	100			252.37	1398.83	9444.91	70735.43	40439.29
moments around the arbitrary origin					n_1 = 2.524	n_2 = 13.988	n_3 = 94.449	n_4 = 707.354	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals.

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f}$ $n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f}$ $n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f}$ $n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\overline{X}_o = -2.5$

$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 0.02$ $m_1 = X = X_o + cn_1 = 0.024$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.6175$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 20.69011$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 166.7094$ $\sigma_\phi = \sqrt{\sigma^2} = 2.7599$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.9842$ $SK = \frac{\sqrt{b_1}}{2} = 0.4921$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.8733$ $K = b_2 - 3 = -0.1267$

Summary: $\overline{X} = 0.024$ $M_\phi = 0.02$ $\sigma_\phi = 2.7599$ SK = 0.4921

$\sqrt{b_1} = 0.9842$ $b_2 = 2.8733$ K = -0.1267

Table 75

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-22 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		5.91		-6	-35.46	212.76	-1276.56	7659.36	14189.91
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	11.76		-5	-58.80	294.0	-1470.0	7350.0	15240.96
$\bar{1}$ - 0	$\bar{0}$.5	10.00		-4	-40.0	160.0	-640.0	2560.0	6250.0
0 - 1	0.5	7.26		-3	-21.78	65.34	-196.02	588.06	1858.56
1 - 2	1.5	9.61		-2	-19.22	38.44	-76.88	153.76	778.41
2 - 3	2.5	21.82		-1	-21.82	21.82	-21.82	21.82	349.12
3 - 4	$\bar{X}_o$=3.5	24.40		0	0.00	0.00	0.00	0.00	24.40
4 - 5	4.5	4.32		1	4.32	4.32	4.32	4.32	0.00
5 - 6	5.5	2.49		2	4.98	9.96	19.92	39.84	2.49
6 - 7	6.5	1.23		3	3.69	11.07	33.21	99.63	19.68
7 - 8	7.5	0.76		4	3.04	12.16	48.64	194.56	61.56
8 - 9	8.5	0.44		5	2.20	11.0	55.0	275.0	112.64
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-178.85	840.87	-3520.19	18946.35	38887.73
moments around the arbitrary origin					n_1 = -1.789	n_2 = 8.409	n_3 = -35.202	n_4 = 189.464	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 1.71 \qquad m_1 = X = X_o + cn_1 = 1.711$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.2085 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -1.5221$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 68.3075 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.2822$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.128 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.064$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.518 \qquad K = b_2 - 3 = -0.482$$

Summary: $\bar{X} = 1.711$ $\quad$ $M_\phi = 1.71$ $\quad$ $\sigma_\phi = 2.2822$ $\quad$ SK = -0.064

$\sqrt{b_1} = -0.128$ $\quad$ $b_2 = 2.518$ $\quad$ K = -0.482

Table 76

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-23 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		14.66		-1	-14.66	14.66	-14.66	14.66	234.56
$\bar{2}$ - $\bar{1}$	$X_0=\bar{1}.5$	19.33		0	0.00	0.00	0.00	0.00	19.33
$\bar{1}$ - 0	$\bar{0}.5$	14.12		1	14.12	14.12	14.12	14.12	0.00
0 - 1	0.5	6.48		2	12.96	25.92	51.84	103.68	6.48
1 - 2	1.5	6.61		3	19.83	59.49	178.47	535.41	105.76
2 - 3	2.5	14.75		4	59.0	236.0	944.0	3776.0	1194.75
3 - 4	3.5	16.46		5	82.30	411.50	2057.50	10287.50	4213.76
4 - 5	4.5	3.12		6	18.72	112.32	673.92	4043.52	1950.0
5 - 6	5.5	2.87		7	20.09	140.63	984.41	6890.87	3719.52
6 - 7	6.5	0.90		8	7.20	57.60	460.80	3686.40	2160.90
7 - 8	7.5	0.45		9	4.05	36.45	328.05	2952.45	1843.20
8 - 9	8.5	0.25		10	2.50	25.0	250.0	2500.0	1640.25
$\bar{9}$		0.00		11	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			226.11	1133.69	5928.45	34804.61	17088.51
moments around the arbitrary origin					$n_1 =$ 2.261	$n_2 =$ 11.337	$n_3 =$ 59.285	$n_4 =$ 348.046	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\bar{X}_o = -1.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 0.76 \qquad m_1 = X = X_o + cn_1 = 0.761$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.2249 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 5.5030$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 81.2072 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.4949$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3543 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.1771$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.0959 \qquad K = b_2 - 3 = -0.9041$$

Summary: $\bar{X} = 0.761$ $M_\phi = 0.76$ $\sigma_\phi = 2.4949$ SK = 0.1771

$\sqrt{b_1} = 0.3543$ $b_2 = 2.0959$ K = -0.9041

Table 77

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-24 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		17.29		-5	-86.45	432.25	-2161.25	10806.25	22407.84
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	14.44		-4	-57.76	231.04	-924.16	3696.64	9025.00
$\bar{1}$ - 0	$\bar{0}$.5	10.61		-3	-31.83	95.49	-286.47	859.41	2716.16
0 - 1	0.5	7.64		-2	-15.28	30.56	-61.12	122.24	618.84
1 - 2	1.5	10.65		-1	-10.65	10.65	-10.65	10.65	170.40
2 - 3	$\bar{X}_0$=2.5	20.33		0	0.00	0.00	0.00	0.00	20.33
3 - 4	3.5	14.26		1	14.26	14.26	14.26	14.26	0.00
4 - 5	4.5	2.39		2	4.78	9.56	19.12	38.24	2.39
5 - 6	5.5	1.53		3	4.59	13.77	41.31	123.93	24.48
6 - 7	6.5	0.54		4	2.16	8.64	34.56	138.24	43.74
7 - 8	7.5	0.12		5	0.60	3.00	15.00	75.00	30.72
8 - 9	8.5	0.20		6	1.20	7.20	43.20	259.20	125.0
$\bar{9}$		0.00		7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-174.38	845.77	-3276.2	16144.06	35184.90
moments around the arbitrary origin					n_1 = -1.744	n_2 = 8.458	n_3 = -32.762	n_4 = 161.441	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\overline{X}_o = 2.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 0.75 \qquad m_1 = X = X_o + cn_1 = 0.756$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.4165 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.8816$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 59.4915 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.3273$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.0699 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.0349$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.0279 \qquad K = b_2 - 3 = -0.9721$$

Summary: $\overline{X} = 0.756$ $\quad$ $M_\phi = 0.75$ $\quad$ $\sigma_\phi = 2.3273$ $\quad$ SK = 0.0349

$\sqrt{b_1} = 0.0699$ $\quad$ $b_2 = 2.0279$ $\quad$ K = -0.9721

Table 78

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-25 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		11.49		-5	-57.45	287.25	-1436.25	7181.25	14891.04
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	18.44		-4	-73.76	295.04	-1180.16	4720.64	11525.00
$\bar{1}$ - 0	$\bar{0}.5$	13.77		-3	-41.31	123.93	-371.79	1115.37	3525.12
0 - 1	0.5	8.63		-2	-17.26	34.52	-69.04	138.08	699.03
1 - 2	1.5	10.55		-1	-10.55	10.55	-10.55	10.55	168.80
2 - 3	$\bar{X}_o$=2.5	20.59		0	0.00	0.00	0.00	0.00	20.59
3 - 4	3.5	12.49		1	12.49	12.49	12.49	12.49	0.00
4 - 5	4.5	1.98		2	3.96	7.92	15.84	31.68	1.98
5 - 6	5.5	1.38		3	4.14	12.42	37.26	111.78	22.08
6 - 7	6.5	0.44		4	1.76	7.04	28.16	112.64	35.64
7 - 8	7.5	0.17		5	0.85	4.25	21.25	106.25	43.52
8 - 9	8.5	0.14		6	0.84	5.04	30.24	181.44	87.50
$\bar{9}$		0.00		7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-176.29	800.45	-2922.55	13722.17	31020.30
moments around the arbitrary origin					n_1 = -1.763	n_2 = 8.005	n_3 = -29.226	n_4 = 137.222	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 2.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.74 \qquad m_1 = X = \bar{X}_o + cn_1 = 0.737$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.8969 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 2.1534$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 51.4214 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.2128$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.1987 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.0993$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.1447 \qquad K = b_2 - 3 = 0.8553$$

Summary: $\bar{X} = 0.737$ $\quad$ $M_\phi = 0.74$ $\quad$ $\sigma_\phi = 2.2128$ $\quad$ SK = 0.0993

$\sqrt{b_1} = 0.1987$ $\quad$ $b_2 = 2.1447$ $\quad$ K = 0.8553

Table 79

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-27 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		15.57		-1	-15.57	15.57	-15.57	15.57	249.12
$\bar{2} - \bar{1}$	$X_o=\bar{1}.5$	20.17		0	0.00	0.00	0.00	0.00	20.17
$\bar{1} - 0$	$\bar{0}.5$	15.48		1	15.48	15.48	15.48	15.48	0.00
0 - 1	0.5	11.49		2	22.98	45.96	91.92	183.84	11.49
1 - 2	1.5	8.22		3	24.66	73.98	221.94	665.82	131.52
2 - 3	2.5	10.59		4	42.36	169.44	677.76	2711.04	857.79
3 - 4	3.5	12.34		5	61.70	308.50	1542.50	7712.50	3159.04
4 - 5	4.5	3.33		6	19.98	119.88	719.28	4315.68	2081.25
5 - 6	5.5	1.63		7	11.41	79.87	559.09	3913.63	2112.48
6 - 7	6.5	0.76		8	6.08	48.64	389.12	3112.96	1824.76
7 - 8	7.5	0.19		9	1.71	15.39	138.51	1246.59	778.24
8 - 9	8.5	0.23		10	2.70	27.0	270.0	2700.0	1771.47
$\bar{9}$		0.00		11	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			193.49	919.71	4610.03	26593.11	12997.33
moments around the arbitrary origin					$n_1 =$ 1.935	$n_2 =$ 9.197	$n_3 =$ 46.1	$n_4 =$ 265.931	

m = midpoint of each class $\quad f$ = frequency $\quad \overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \overline{X}_o = -1.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.44 \qquad m_1 = X = X_o + cn_1 = 0.435$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.4528 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 7.2015$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 73.6724 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.3351$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.5656 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.2828$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.4779 \qquad K = b_2 - 3 = -0.5221$$

Summary: $\overline{X} = 0.435$ $\quad M_\phi = 0.44$ $\quad \sigma_\phi = 2.3351$ $\quad SK = 0.2828$

$\sqrt{b_1} = 0.5656$ $\quad b_2 = 2.4779$ $\quad K = -0.5221$

Table 80

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-28 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		13.33		-6	-79.98	479.88	-2879.28	17275.68	32005.33
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	15.09		-5	-75.45	377.25	-1886.25	9431.25	19556.64
$\bar{1}$ - 0	$\bar{0}.5$	13.49		-4	-53.96	215.84	-863.36	3453.44	8431.25
0 - 1	0.5	12.37		-3	-37.11	111.33	-333.99	1001.97	3166.72
1 - 2	1.5	8.46		-2	-16.92	33.84	-67.68	135.36	685.26
2 - 3	2.5	12.04		-1	-12.04	12.04	-12.04	12.04	192.64
3 - 4	$\bar{X}_o$=3.5	16.31		0	0.00	0.00	0.00	0.00	16.31
4 - 5	4.5	5.15		1	5.15	5.15	5.15	5.15	0.00
5 - 6	5.5	1.77		2	3.54	7.08	14.16	28.32	1.72
6 - 7	6.5	0.96		3	2.88	8.64	25.92	77.79	15.36
7 - 8	7.5	0.51		4	2.04	8.16	32.64	130.56	41.31
8 - 9	8.5	0.52		5	2.60	13.0	65.0	325.0	133.12
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-259.23	1272.21	-5899.73	31876.56	64245.66
moments around the arbitrary origin					n_1 =	n_2 =	n_3 =	n_4 =	
					-2.592	12.722	-58.997	318.766	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.91$$

$$m_1 = X = X_o + cn_1 = 0.908$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.0036$$

$$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 5.1012$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 84.5031$$

$$\sigma_\phi = \sqrt{\sigma^2} = 2.4502$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3467$$

$$SK = \frac{\sqrt{b_1}}{2} = 0.1733$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.3446$$

$$K = b_2 - 3 = -0.6554$$

Summary: $\bar{X} = 0.908$ $M_\phi = 0.91$ $\sigma_\phi = 2.4502$ SK = 0.1733

$\sqrt{b_1} = 0.3467$ $b_2 = 2.3446$ K = -0.6554

Table 81

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-29 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$		10.05		-1	-10.05	10.05	-10.05	10.05	160.80
$\overline{2}$ - $\overline{1}$	$X_o=\overline{1}.5$	17.27		0	0.00	0.00	0.00	0.00	17.27
$\overline{1}$ - 0	$\overline{0}.5$	15.80		1	15.80	15.80	15.80	15.80	0.00
0 - 1	0.5	12.71		2	25.42	50.84	101.68	203.36	12.71
1 - 2	1.5	7.63		3	22.89	68.67	206.01	618.03	122.08
2 - 3	2.5	11.10		4	44.40	177.60	710.40	2841.60	899.10
3 - 4	3.5	14.57		5	72.85	364.25	1821.25	9106.25	3729.92
4 - 5	4.5	5.17		6	31.02	186.12	1116.72	6700.32	3231.25
5 - 6	5.5	2.42		7	16.94	118.58	830.06	5810.42	3136.32
6 - 7	6.5	1.07		8	8.56	68.48	547.84	4382.72	2569.07
7 - 8	7.5	1.06		9	9.54	85.86	772.74	6954.66	4341.76
8 - 9	8.5	1.15		10	11.50	115.0	1150.0	11500.0	7545.15
$\overline{9}$		0.00		11	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			248.87	1261.25	7262.45	48143.21	25765.43
moments around the arbitrary origin					n_1 = 2.489	n_2 = 12.613	n_3 = 72.625	n_4 = 481.432	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\overline{X}_o = -1.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 0.99 \qquad m_1 = X = X_o + cn_1 = 0.989$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.4179 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 9.2830$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 112.0723 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.5333$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.5709 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.2854$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.7211 \qquad K = b_2 - 3 = -0.2789$$

Summary: $\overline{X} = 0.989$ $\quad$ $M_\phi = 0.99$ $\quad$ $\sigma_\phi = 2.5333$ $\quad$ SK = 0.2854

$\sqrt{b_1} = 0.5709$ $\quad$ $b_2 = 2.7211$ $\quad$ K = -0.2789

Table 82

Computation of Statistics from the first moments of a frequency distribution of a Sample No. B-30 from Pediment B at Wadi Al-Quway'iyah area.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		10.79		-6	-64.74	388.44	-2330.64	13983.84	25906.79
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	15.30		-5	-76.50	382.50	-1912.50	9562.50	19828.80
$\bar{1}$ - 0	$\bar{0}$.5	12.22		-4	-48.88	195.52	-782.08	3128.32	7637.50
0 - 1	0.5	9.58		-3	-28.74	86.22	-258.66	775.98	2452.48
1 - 2	1.5	6.90		-2	-13.80	27.60	-55.20	110.40	558.90
2 - 3	2.5	12.33		-1	-12.33	12.33	-12.33	12.33	197.28
3 - 4	$\bar{X}_o$=3.5	16.32		0	0.00	0.00	0.00	0.00	16.32
4 - 5	4.5	9.89		1	9.89	9.89	9.89	9.89	0.00
5 - 6	5.5	2.41		2	4.82	9.64	19.28	38.56	2.41
6 - 7	6.5	1.07		3	3.21	9.63	28.89	86.67	17.12
7 - 8	7.5	1.05		4	4.20	16.80	67.20	268.80	85.05
8 - 9	8.5	2.07		5	10.35	51.75	258.75	1293.75	529.92
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-212.52	1190.32	-4967.4	29271.04	57232.57
moments around the arbitrary origin					n_1 = -2.125	n_2 = 11.903	n_3 = -49.674	n_4 = 292.71	

m = midpoint of each class $\qquad f$ = frequency $\qquad \overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\qquad M_\phi$ = logarithmetic mean $\qquad c$ = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness $\qquad \sigma_\phi$ = standard deviation $\qquad$ K = kurtosis $\qquad \overline{X}_o = 3.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 1.37 \qquad m_1 = X = X_o + cn_1 = 1.375$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.3874 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 7.0164$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 131.8043 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.7179$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3494 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.1747$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.4154 \qquad K = b_2 - 3 = -0.5846$$

Summary: $\overline{X} = 1.375 \qquad M_\phi = 1.37 \qquad \sigma_\phi = 2.7179 \qquad SK = 0.1747$

$\sqrt{b_1} = 0.3494 \qquad b_2 = 2.4154 \qquad K = -0.5846$

Table 83

Two way analysis of variance for the phi mean M_ϕ of pediment A

Distance / Depth	1150 m. A	900 m. B	650 m. C	400 m. D	150 m. E	B_j
1 surface	2.20	0.30	2.25	1.32	1.21	$\bar{X}_{.1}=1.4560$
2 1 m.	5.67	2.52	2.13	2.50	1.72	$\bar{X}_{.2}=2.9090$
3 2 m.	5.35	3.60	1.11	3.91	0.91	$\bar{X}_{.3}=2.9760$
4 3 m.	6.13	6.14	3.07	2.85	1.83	$\bar{X}_{.4}=4.0040$
a_i	$\bar{X}_{.A}=4.8375$	$\bar{X}_{.B}=3.1400$	$\bar{X}_{.C}=2.1400$	$\bar{X}_{.D}=2.6450$	$\bar{X}_{.E}=1.4175$	$\sum X=2.8360$

TSS = 59.6893
RSS = 16.4670
n - 1 = 3
RMS = 5.4890
CSS = 26.5258
m - 1 = 4
CMS = 6.6314

ESS = 16.6965
(n-1)(m-1) = 12
EMS = 1.3913
F_r = 3.9452
F_c = 4.7663
$SE(d_r)$ = 0.8340
$SE(d_c)$ = 0.7459

Table 84

Two way analysis of variance for the standard deviation (σ_ϕ) of samples from pediment A

Distance / Depth	1150 m. A	900 m. B	650 m. C	400 m. D	150 m. E	B_j
1 surface	0.7501	1.1817	1.0143	2.3633	2.2012	$\bar{X}.1=1.5021$
2 1 m.	1.8461	1.6057	1.7279	2.0092	2.7568	$\bar{X}.2=1.9891$
3 2 m.	2.3668	2.9457	2.2938	2.5458	2.1592	$\bar{X}.3=2.4622$
4 3 m.	2.7187	1.6595	3.2659	2.0584	2.5598	$\bar{X}.4=2.4524$
a_i	$\bar{X}.A=1.9204$	$\bar{X}.B=1.8481$	$\bar{X}.C=2.0754$	$\bar{X}.D=2.2441$	$\bar{X}.E=2.4192$	$\Sigma X=2.1014$

TSS = 7.9892
RSS = 3.1300
n − 1 = 3
RMS = 1.0433
CSS = 0.8798
m − 1 = 4
CMS = 0.2199

ESS = 3.9794
(n−1)(m−1) = 12
EMS = 0.3316
F_r = 3.1462
F_c = 0.6631
SE(d_r) = 0.4071
SE(d_c) = 0.3641

Table 85

Two way analysis of variance for the skewness (SK) of samples from pediment A

Distance / Depth	1150 m. A	900 m. B	650 m. C	400 m. D	150 m. E	B_j
1 surface	0.3456	0.0883	1.1411	0.0003	0.7254	$\overline{X}_{.1}=0.4601$
2 1 m.	0.3611	0.4637	0.2801	0.0346	-0.0645	$\overline{X}_{.2}=0.2150$
3 2 m.	0.1906	0.1131	-0.0227	0.2532	-0.0642	$\overline{X}_{.3}=0.0940$
4 3 m.	-0.1211	-0.0925	-0.3807	0.6421	0.0293	$\overline{X}_{.4}=0.0154$
a_i	$\overline{X}_{.A}=0.1940$	$\overline{X}_{.B}=0.1431$	$\overline{X}_{.C}=0.2544$	$\overline{X}_{.D}=0.2325$	$\overline{X}_{.E}=0.1565$	$\sum X=0.1961$

TSS = 2.3138
RSS = 0.5659
n - 1 = 3
RMS = 0.1886
CSS = 0.0365
m - 1 = 4
CMS = 0.0091

ESS = 1.7114
(n-1)(m-1) = 12
EMS = 0.1426
F_r = 1.3225
F_c = 0.0638
$SE(d_r)$ = 0.2670
$SE(d_c)$ = 0.2387

Table 86

Two way analysis of variance for Kurtosis (K) of samples from pediment A

Distance / Depth	1150 m. A	900 m. B	650 m. C	400 m. D	150 m. E	B_j
1 surface	-0.1918	2.7108	0.3813	-0.8749	-0.4875	$\bar{X}.1=0.3075$
2 1 m.	-0.2911	3.6380	0.8947	2.4185	0.7695	$\bar{X}.2=1.4859$
3 2 m.	-0.6879	-0.2004	-1.2241	0.0461	2.1017	$\bar{X}.3=0.0070$
4 3 m.	-1.0338	-1.0990	-0.6082	1.6045	-0.3595	$\bar{X}.4=-0.2992$
a_i	$\bar{X}.A=-0.5511$	$\bar{X}.B=1.2623$	$\bar{X}.C=-0.1390$	$\bar{X}.D=0.7985$	$\bar{X}.E=0.5060$	$\sum X=0.3753$

TSS = 38.0583
RSS = 9.1433
n − 1 = 3
RMS = 3.0477
CSS = 8.4242
m − 1 = 4
CMS = 2.1060

ESS = 20.4908
(n−1)(m−1) = 12
EMS = 1.7075
F_r = 1.7848
F_c = 1.2333
$SE(d_r)$ = 0.9239
$SE(d_c)$ = 0.8264

Table 87

Two way analysis of variance for the phi mean M_ϕ of pediment B

Distance / Depth	1350 m. A	1100 m. B	850 m. C	600 m. D	350 m. E	100 m. F	B_j
1 surface	1.157	-0.13	1.41	2.16	0.02	0.74	$\overline{X}_{.1}=0.8928$
2 1 m.	2.12	0.75	1.51	2.09	1.71	0.44	$\overline{X}_{.2}=1.4366$
3 2 m.	2.36	0.8	1.33	2.63	0.76	0.91	$\overline{X}_{.3}=1.4650$
4 3 m.	1.99	0.05	0.68	2.84	0.75	0.99	$\overline{X}_{.4}=1.2166$
5 4 m.	2.46	1.57	-0.22	2.61	2.36	1.37	$\overline{X}_{.5}=1.6916$
a_i	$\overline{X}_{.A}=2.0174$	$\overline{X}_{.B}=0.6080$	$\overline{X}_{.C}=0.9420$	$\overline{X}_{.D}=2.4660$	$\overline{X}_{.E}=1.1200$	$\overline{X}_{.F}=0.8900$	$\sum X=1.3405$

TSS = 22.6270
RSS = 2.1856
n - 1 = 4
RMS = 0.5464
CSS = 13.3621
m - 1 = 5
CMS = 2.6724

ESS = 7.0793
(n-1)(m-1) = 20
EMS = 0.3539
F_r = 1.5439
F_c = 7.5512
$SE(d_r)$ = 0.3761
$SE(d_c)$ = 0.3433

Table 88

Two way analysis of variance for the standard deviation σ_ϕ of pediment B

Distance / Depth	1350 m. A	1100 m. B	850 m. C	600 m. D	350 m. E	100 m. F	B_j
1 surface	2.7533	2.5931	2.4108	2.5777	2.7599	2.2128	$\bar{X}.1=2.5512$
2 1 m.	2.6907	2.7158	2.4008	2.7026	2.2822	2.3351	$\bar{X}.2=2.5212$
3 2 m.	3.0943	2.7929	2.2380	2.5855	2.4949	2.4502	$\bar{X}.3=2.6093$
4 3 m.	2.9633	2.8206	2.3527	2.6075	2.3273	2.5333	$\bar{X}.4=2.6007$
5 4 m.	2.2745	2.5433	2.0212	2.6728	2.7959	2.7179	$\bar{X}.5=2.5042$
a_i	$\bar{X}.A=2.7552$	$\bar{X}.B=2.6931$	$\bar{X}.C=2.2847$	$\bar{X}.D=2.6292$	$\bar{X}.E=2.5320$	$\bar{X}.F=2.4495$	$\sum X=2.5573$

TSS = 1.6957
RSS = 0.0573
n - 1 = 4
RMS = 0.0143
CSS = 0.7513
m - 1 = 5
CMS = 0.1502

ESS = 0.8871
(n-1)(m-1) = 20
EMS = 0.0443
F_r = 0.3227
F_c = 3.3905
$SE(d_r)$ = 0.1330
$SE(d_c)$ = 0.1212

Table 89

Two way analysis of variance for the skewness SK of pediment B

Distance / Depth	1350 m. A	1100 m. B	850 m. C	600 m. D	350 m. E	100 m. F	B_j
1 surface	-0.0317	0.2453	0.0238	0.0004	0.4921	0.0993	$\bar{X}.1$=0.1382
2 1 m.	-0.0388	0.1673	-0.-190	0.1965	-0.0640	0.2828	$\bar{X}.2$=0.0874
3 2 m.	0.1546	0.2306	-0.0382	-0.2060	0.1771	0.1733	$\bar{X}.3$=0.0819
4 3 m.	-0.0043	0.5322	0.2404	-0.167	0.0349	0.2854	$\bar{X}.4$=0.1786
5 4 m.	0.0426	0.1944	0.5317	0.0162	0.0332	0.1747	$\bar{X}.5$=0.1654
a_i	$\bar{X}.A$=0.0244	$\bar{X}.B$=0.2739	$\bar{X}.C$=0.1477	$\bar{X}.D$=-0.0091	$\bar{X}.E$=0.1346	$\bar{X}.F$=0.2031	$\sum X$=0.1303

TSS = 0.9161
RSS = 0.0470
n - 1 = 4
RMS = 0.0117
CSS = 0.2748
m - 1 = 5
CMS = 0.0549

ESS = 0.5943
(n-1)(m-1) = 20
EMS = 0.0297
F_r = 0.3939
F_c = 1.8484
$SE(d_r)$ = 0.1086
$SE(d_c)$ = 0.0994

Table 90

Two way analysis of variance for the Kurtosis K of pediment B

Distance / Depth	1350 m. A	1100 m. B	850 m. C	600 m. D	350 m. E	100 m. F	B_j
1 surface	-1.1480	-1.4196	-0.6019	-0.1891	-0.1267	0.8553	$\bar{X}.1$=-0.4383
2 1 m.	0.0085	-0.7018	-0.6306	0.2983	-0.4820	-0.5221	$\bar{X}.2$=-0.3382
3 2 m.	0.9560	-0.3488	-0.7320	-0.0883	-0.9041	-0.6554	$\bar{X}.3$=-0.4388
4 3 m.	-0.2965	0.6813	-0.4271	0.0068	-0.9721	-0.2789	$\bar{X}.4$=-0.2144
5 4 m.	0.7485	-0.1041	1.0203	-0.2827	-0.4625	-0.5846	$\bar{X}.5$= 0.0558
a_i	$\bar{X}.A$=-0.1183	$\bar{X}.B$=-0.3786	$\bar{X}.C$=-0.2742	$\bar{X}.D$=-0.0510	$\bar{X}.E$=-0.5894	$\bar{X}.F$=-0.2371	ΣX=-0.2748

TSS = 9.6223
RSS = 1.0238
n - 1 = 4
RMS = 0.2559
CSS = 0.9289
m - 1 = 5
CMS = 0.1857

ESS = 7.6696
(n-1)(m-1) = 20
EMS = 0.3834
F_r = 0.6674
F_c = 0.4843
$SE(d_r)$ = 0.3915
$SE(d_c)$ = 0.3574

Table 91

Summary of the analysis of variance (two way classification without replicates) of the means and standard deviations of samples from pediment A

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	Fo.10	Fo.05	Fo.025
d=4	Between depths	d-1=3	16.4670	5.4890	3.9452**	2.61	3.49	4.47
D=5	Among distances	D-1=4	26.5258	0.6314	4.7663***	2.48	3.26	4.12
	Error	(d-1)(D-1) = 12	16.6965	1.3913				
dD=20		dD-1 = 19	TSS= 59.6893					
	SE (d_r) = 0.8340				SE (d_c) = 0.7459			

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	Fo.10	Fo.05	Fo.025
d=4	Between depths	d-1=3	3.1300	1.0433	3.1462	2.61*	3.49	4.47
D=5	Among distances	D-1=4	0.8798	0.2199	0.6631	2.48	3.26	4.12
	Error	(d-1)(D-1) = 12	3.9794	0.3316				
dD=20		dD-1 = 19	TSS= 7.9892					
	SE (d_r) = 0.4071				SE (d_c) = 0.3641			

Table 92

Summary of the analysis of variance (two way classification without replicates) of the means and the standard deviation of samples from pediment B

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	Fo.10	Fo.05	Fo.025
d=5	Between depths	d-1=4	2.1856	0.5464	1.5439	2.25	2.86	3.51
D=6	Among distances	D-1=5	13.3621	2.6724	7.5512***	2.16	2.71	Fo.01 4.17
	Error	(d-1)(D-1) = 20	7.0793	0.3539				
dD=30		dD-1 = 29	22.6270					

SE (d_r) = 0.3761 SE (d_c) = 0.343

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	Fo.10	Fo.05	Fo.025
d=5	Between depths	d-1=4	0.0573	0.0143	0.3227	2.25	2.86	3.51
D=6	Among distances	D-1=5	0.7513	0.1502	3.3905***	2.16	2.71	3.29
	Error	(d-1)(D-1) = 20	0.8871	0.0443				
dD=30		dD-1 = 29	1.6957					

SE (d_r) = 0.1330 SE (d_c) = 0.1212

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Table 93 Shape measurements of pebbles

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	55.000	40.000	21.000	5.000	24190.262	1727.876	0.585	2.262	181.818		BLADED
2	60.000	30.000	14.000	5.000	13194.688	1413.717	0.478	3.214	166.667	VERY	BLADED
3	37.000	21.000	19.000	5.000	7729.887	610.254	0.775	1.526	270.270	COMPACT	ELONGATED
4	47.000	45.000	23.000	8.000	25470.461	1661.117	0.630	2.000	340.425		PLATY
5	57.000	43.000	21.000	9.000	26950.152	1925.011	0.565	2.381	315.789		BLADED
6	60.000	33.000	30.000	6.000	31101.766	1555.088	0.769	1.550	200.000		ELONGATED
7	52.000	33.000	30.000	9.000	26954.863	1347.743	0.806	1.417	346.154	COMPACT	ELONGATED
8	45.000	42.000	40.000	8.000	39584.066	1484.402	0.946	1.087	355.555	COMPACT	
9	42.000	40.000	18.000	3.000	15833.625	1319.469	0.578	2.278	142.857		PLATY
10	55.000	30.000	18.000	6.000	15550.883	1295.907	0.581	2.361	218.182	VERY	ELONGATED
11	57.000	30.000	20.000	4.000	17907.078	1343.031	0.616	2.175	140.351		ELONGATED
12	65.000	60.000	36.000	4.500	73513.250	3063.053	0.693	1.736	138.462	COMPACT	PLATY
13	51.000	30.000	18.000	5.000	14419.910	1201.659	0.596	2.250	196.078		BLADED
14	45.000	37.000	14.000	4.000	12205.086	1307.688	0.490	2.929	177.778	VERY	PLATY
15	54.000	35.000	28.000	5.000	27708.844	1484.402	0.746	1.589	185.185	COMPACT	ELONGATED
16	58.000	35.000	11.000	4.000	11691.957	1594.358	0.391	4.227	137.931	VERY	BLADED
17	40.000	27.000	19.000	3.000	10744.246	848.230	0.694	1.763	150.000		BLADED
18	30.000	11.000	10.000	3.000	1727.876	259.181	0.672	2.050	200.000	VERY	ELONGATED
19	30.000	18.000	11.000	2.500	3110.177	424.115	0.607	2.182	166.667		BLADED
20	25.000	25.000	16.000	6.000	5235.984	490.874	0.743	1.563	480.000	COMPACT	PLATY
21	34.000	18.000	10.000	3.000	3204.424	480.664	0.547	2.600	176.471	VERY	ELONGATED
22	25.000	20.000	12.000	4.000	3141.593	392.699	0.660	1.875	320.000		BLADED
23	37.000	27.000	17.000	7.000	8892.277	784.613	0.661	1.882	378.378		BLADED
24	55.000	31.000	14.000	5.000	12498.301	1339.104	0.486	3.071	181.818	VERY	BLADED
25	45.000	25.000	20.000	6.000	11780.969	883.573	0.708	1.750	266.667		ELONGATED
26	48.000	25.000	20.000	3.000	12566.367	942.478	0.693	1.825	125.000		ELONGATED
27	35.000	26.000	18.000	5.500	8576.547	714.712	0.709	1.694	314.286	COMPACT	BLADED
28	30.000	25.000	20.000	4.000	7853.980	589.049	0.811	1.375	266.667	COMPACT	BLADED
29	40.000	30.000	11.000	4.000	6911.500	942.478	0.465	3.182	200.000	VERY	BLADED
30	45.000	40.000	22.000	9.000	20734.508	1413.717	0.645	1.932	400.000		PLATY
31	63.000	49.000	32.000	6.000	51723.180	2424.524	0.692	1.750	190.476	COMPACT	BLADED
32	55.000	38.000	34.000	6.000	37206.926	1641.482	0.821	1.368	218.182	COMPACT	ELONGATED
33	65.000	25.000	19.000	4.000	16166.109	1276.272	0.606	2.368	123.077	VERY	ELONGATED
34	55.000	32.000	20.000	3.500	18430.676	1382.301	0.610	2.175	127.273		BLADED
35	35.000	17.000	10.000	3.500	3115.413	467.312	0.552	2.600	200.000	VERY	ELONGATED
36	35.000	17.000	12.000	4.000	3738.495	467.312	0.623	2.167	228.571		ELONGATED
37	35.000	25.000	19.000	4.000	8704.828	687.223	0.744	1.579	228.571	COMPACT	BLADED
38	37.000	22.000	12.000	5.000	5114.512	639.314	0.561	2.458	270.270	VERY	BLADED
39	30.000	15.000	13.000	3.000	3063.053	353.429	0.721	1.731	200.000		ELONGATED
40	34.000	21.000	17.000	3.000	6355.441	560.774	0.740	1.618	176.471		ELONGATED
41	23.000	17.000	15.000	4.000	3070.907	307.091	0.832	1.333	347.826	COMPACT	ELONGATED
42	36.000	23.000	12.000	3.000	5202.477	650.310	0.558	2.458	166.667	VERY	BLADED
43	27.000	15.000	10.000	3.000	2120.575	318.086	0.627	2.100	222.222		ELONGATED
44	31.000	20.000	10.000	2.000	3246.312	486.947	0.544	2.550	129.032	VERY	BLADED
45	31.000	21.000	18.000	2.500	6135.527	511.294	0.792	1.444	161.290	COMPACT	ELONGATED
46	35.000	16.000	12.000	2.000	3518.584	439.823	0.636	2.125	114.286		ELONGATED
47	40.000	17.000	15.000	4.000	5340.707	534.071	0.692	1.900	200.000		ELONGATED
48	31.000	16.000	14.000	4.000	3635.870	389.557	0.734	1.679	258.064		ELONGATED
49	32.000	17.000	17.000	2.500	4842.238	427.257	0.810	1.441	156.250	COMPACT	ELONGATED
50	33.000	17.000	11.000	2.500	3231.128	440.608	0.600	2.273	151.515	VERY	ELONGATED
51	31.000	18.000	17.000	3.000	4966.855	438.252	0.803	1.441	193.548	COMPACT	ELONGATED
52	39.000	18.000	17.000	2.000	6248.625	551.349	0.744	1.676	102.564		ELONGATED
53	30.000	18.000	15.000	3.000	4241.148	424.115	0.747	1.600	200.000		ELONGATED
54	23.000	21.000	18.000	8.000	4552.164	379.347	0.875	1.222	695.652	COMPACT	
55	27.000	22.000	12.000	5.000	3732.212	466.526	0.624	2.042	370.370		BLADED
56	23.000	15.000	12.000	2.500	2167.699	270.962	0.747	1.583	217.391	COMPACT	ELONGATED
57	31.000	26.000	15.000	3.500	6330.309	633.031	0.654	1.900	225.806		PLATY
58	25.000	23.000	10.000	3.500	3010.693	451.604	0.558	2.400	280.000		PLATY
59	37.000	16.000	16.000	4.000	4959.527	464.956	0.756	1.656	216.216		ELONGATED
60	31.000	22.000	10.000	3.000	3570.944	535.641	0.527	2.650	193.548	VERY	BLADED
61	35.000	23.000	16.000	5.000	6743.949	632.245	0.683	1.813	285.714		BLADED
62	25.000	20.000	11.000	5.000	2879.793	392.699	0.623	2.045	400.000		BLADED
63	30.000	16.000	11.000	3.000	2764.601	376.991	0.632	2.091	200.000		ELONGATED
64	32.000	16.000	13.000	3.000	3485.073	402.124	0.691	1.846	187.500		ELONGATED
65	35.000	21.000	12.000	4.000	4618.141	577.268	0.581	2.333	228.571		BLADED
66	27.000	14.000	14.000	2.000	2770.885	296.880	0.803	1.464	148.148	COMPACT	ELONGATED
67	50.000	27.000	16.000	3.500	11309.730	1060.287	0.575	2.406	140.000	VERY	ELONGATED
68	50.000	23.000	12.000	4.000	7225.660	903.208	0.500	3.042	160.000	VERY	ELONGATED
69	35.000	20.000	12.000	4.000	4398.227	549.779	0.590	2.292	228.571		BLADED
70	35.000	29.000	18.000	5.000	9566.148	797.179	0.683	1.778	285.714	COMPACT	BLADED
71	40.000	21.000	21.000	5.000	9236.281	659.734	0.807	1.452	250.000	COMPACT	ELONGATED
72	36.000	30.000	19.000	3.500	10744.246	848.230	0.694	1.737	194.444	COMPACT	BLADED
73	46.000	37.000	17.000	5.500	15149.805	1336.748	0.554	2.441	239.130		PLATY
74	35.000	20.000	24.000	3.000	8796.457	549.779	0.937	1.146	171.429	COMPACT	ELONGATED
75	47.000	23.000	17.000	4.000	9622.172	849.015	0.644	2.059	170.213		ELONGATED
76	45.000	27.000	26.000	3.500	16540.484	954.259	0.822	1.385	155.556	COMPACT	ELONGATED
77	46.000	23.000	16.000	4.000	8863.477	830.951	0.623	2.156	173.913		ELONGATED
78	46.000	38.000	30.000	5.000	27457.520	1372.876	0.801	1.400	217.391	COMPACT	BLADED
79	50.000	36.000	19.000	2.000	17907.078	1413.717	0.585	2.263	80.000		BLADED
80	56.000	26.000	14.000	2.000	10673.035	1143.540	0.513	2.929	71.429	VERY	ELONGATED
81	58.040	5.030	5.060	0.0	773.471	229.290	0.444	6.232	0.0	VERY	ELONGATED
82	55.000	25.000	19.000	5.000	13679.016	1079.922	0.640	2.105	181.818		ELONGATED
83	55.000	40.000	32.000	7.000	36861.352	1727.876	0.775	1.484	254.545	COMPACT	BLADED
84	52.000	35.000	21.000	4.500	20011.941	1429.425	0.623	2.071	173.077		BLADED
85	45.000	35.000	18.000	4.000	14844.023	1237.002	0.590	2.222	177.778		BLADED
86	55.000	17.000	16.000	3.000	7833.035	734.347	0.649	2.250	109.091	VERY	ELONGATED
87	56.000	25.000	21.000	3.000	15393.801	1099.557	0.680	1.929	107.143		ELONGATED
88	45.000	40.000	18.000	8.000	16964.598	1413.717	0.565	2.361	355.555		PLATY
89	55.000	47.000	19.000	6.000	25716.551	2030.254	0.519	2.684	218.182		PLATY
90	55.000	26.000	17.000	5.000	12728.684	1123.119	0.587	2.382	181.818	VERY	ELONGATED
91	50.000	25.000	19.000	5.000	12435.469	981.748	0.661	1.974	200.000		ELONGATED
92	35.000	25.000	10.000	5.000	4581.488	687.223	0.485	3.000	285.714	VERY	BLADED
93	51.000	30.000	13.000	3.500	10414.379	1201.659	0.480	3.115	137.255	VERY	BLADED
94	48.000	40.000	23.000	5.000	23122.121	1507.964	0.651	1.913	208.333		PLATY
95	45.000	25.000	10.000	4.000	5890.484	883.573	0.446	3.500	177.778	VERY	BLADED
96	64.000	46.000	11.000	3.000	16956.223	2312.212	0.345	5.000	93.750	VERY	BLADED
97	40.000	30.000	15.000	6.000	9424.777	942.478	0.572	2.333	300.000		BLADED
98	38.000	26.000	20.000	4.000	10346.309	775.973	0.740	1.600	210.526	COMPACT	ELONGATED
99	45.000	32.000	12.000	6.000	9047.785	1130.973	0.464	3.208	266.667	VERY	BLADED
100	40.000	31.000	22.000	4.000	14283.773	973.894	0.731	1.614	200.000	COMPACT	BLADED

Table 94 Shape measurements of pebbles

(II-145)

FAN ONE SITE TWO

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM CLASS
1	85.000	80.000	30.000	9.000	106814.125	5340.707	0.510	2.750	211.765	PLATY
2	98.000	85.000	67.000	9.000	292225.688	6542.363	0.814	1.366	183.673	COMPACTBLADED
3	47.000	40.000	28.000	6.000	27562.238	1476.548	0.747	1.554	255.319	COMPACTBLADED
4	95.000	50.000	45.000	6.500	111919.188	3730.641	0.753	1.611	136.842	ELONGATED
5	80.000	70.000	65.000	7.500	190589.938	4398.227	0.910	1.154	187.500	COMPACT
6	70.000	60.000	47.000	7.000	103358.375	3298.672	0.807	1.383	200.000	COMPACTBLADED
7	49.000	42.000	18.000	9.000	19396.191	1616.349	0.540	2.528	367.347	PLATY
8	45.000	35.000	25.000	7.000	20616.699	1237.002	0.735	1.600	311.111	COMPACTBLADED
9	90.000	70.000	60.000	9.500	197920.313	4948.008	0.830	1.333	211.111	COMPACTELONGATED
10	75.000	62.000	60.000	6.500	146084.000	3652.101	0.918	1.142	173.333	COMPACT
11	45.000	40.000	35.000	8.500	32986.723	1413.717	0.880	1.214	377.778	COMPACT
12	50.000	31.000	18.000	4.000	14608.402	1217.367	0.593	2.250	160.000	BLADED
13	50.000	38.000	31.000	6.000	30839.965	1492.256	0.797	1.419	240.000	COMPACTBLADED
14	55.000	43.000	37.000	8.000	45817.508	1857.467	0.833	1.324	290.909	COMPACTELONGATED
15	50.000	45.000	30.000	3.500	35342.914	1767.146	0.737	1.583	140.000	COMPACTPLATY
16	65.000	50.000	27.000	7.500	45945.789	2552.544	0.608	2.130	230.769	BLADED
17	50.000	38.000	31.000	6.000	30839.965	1492.256	0.797	1.419	240.000	COMPACTBLADED
18	65.000	57.000	27.000	4.000	52378.203	2909.900	0.582	2.259	123.077	PLATY
19	89.000	72.000	56.000	8.000	187892.313	5032.828	0.788	1.438	179.775	COMPACTBLADED
20	49.000	47.000	23.000	3.500	27734.500	1808.772	0.612	2.087	142.857	PLATY
21	45.000	40.000	35.000	8.500	32986.723	1413.717	0.880	1.214	377.778	COMPACT
22	55.000	40.000	25.000	6.500	28797.930	1727.876	0.657	1.900	236.364	BLADED
23	50.000	39.000	32.000	8.000	32672.563	1531.526	0.807	1.391	320.000	COMPACTBLADED
24	53.000	41.000	27.000	9.500	30720.063	1706.670	0.695	1.741	358.490	COMPACTBLADED
25	51.000	50.000	30.000	2.500	40055.305	2002.765	0.707	1.683	98.039	COMPACTPLATY
26	50.000	40.000	30.000	5.500	31415.926	1570.796	0.766	1.500	220.000	COMPACTBLADED
27	47.000	35.000	30.000	8.500	25839.598	1291.980	0.818	1.367	361.702	COMPACTELONGATED
28	50.000	48.000	40.000	8.500	50265.480	1884.956	0.874	1.225	340.000	COMPACT
29	46.000	37.000	32.000	7.000	28517.281	1336.748	0.844	1.297	304.348	COMPACTBLADED
30	50.000	45.000	25.000	4.000	29452.430	1767.146	0.652	1.900	160.000	PLATY
31	47.000	42.000	35.000	6.000	36175.438	1550.376	0.853	1.271	255.319	COMPACT
32	45.000	35.000	30.000	9.000	24740.039	1237.002	0.830	1.333	400.000	COMPACTELONGATED
33	46.000	45.000	34.000	7.500	36850.879	1625.774	0.823	1.338	326.087	COMPACT
34	47.000	45.000	25.000	4.000	27685.285	1661.117	0.666	1.840	170.213	COMPACTPLATY
35	80.000	65.000	55.000	9.500	149749.188	4084.070	0.835	1.318	237.500	COMPACTBLADED
36	51.000	41.000	21.000	5.000	22991.742	1642.267	0.595	2.190	196.078	BLADED
37	47.000	45.000	41.000	9.500	45403.867	1661.117	0.926	1.122	404.255	COMPACT
38	51.000	46.000	29.000	4.500	35622.516	1842.544	0.710	1.672	176.471	COMPACTPLATY
39	53.000	35.000	34.000	6.500	33023.371	1456.914	0.854	1.294	245.283	COMPACTELONGATED
40	50.000	40.000	20.000	5.000	20943.949	1570.796	0.585	2.250	200.000	BLADED
41	45.000	41.000	34.000	7.500	32845.348	1449.060	0.856	1.265	333.333	COMPACT
42	43.000	40.000	30.000	3.500	27017.695	1350.885	0.806	1.383	162.791	COMPACTPLATY
43	43.000	38.000	32.000	3.500	27377.930	1283.341	0.856	1.266	162.791	COMPACT
44	54.000	32.000	30.000	4.500	27143.359	1357.168	0.805	1.433	166.667	COMPACTELONGATED
45	55.000	45.000	20.000	7.000	25918.137	1943.860	0.545	2.500	254.545	PLATY
46	62.000	58.000	33.000	7.500	62134.418	2824.292	0.672	1.818	241.935	COMPACTPLATY
47	60.000	50.000	30.000	5.000	47123.887	2356.194	0.669	1.833	166.667	BLADED
48	65.000	60.000	59.000	9.000	120480.063	3063.053	0.963	1.059	276.923	COMPACT
49	45.000	43.000	23.000	4.500	23302.762	1519.745	0.649	1.913	200.000	COMPACTPLATY
50	72.000	65.000	35.000	5.000	85765.438	3675.663	0.640	1.957	138.889	PLATY
51	55.000	50.000	49.000	6.000	70554.875	2159.845	0.956	1.071	218.182	COMPACT
52	46.000	43.000	40.000	8.000	41427.133	1553.517	0.932	1.112	347.826	COMPACT
53	59.000	53.000	39.000	3.500	63854.441	2455.940	0.786	1.436	118.644	COMPACTPLATY
54	45.000	35.000	30.000	9.000	24740.039	1237.002	0.830	1.333	400.000	COMPACTELONGATED
55	58.000	55.000	46.000	7.000	76832.875	2505.420	0.872	1.228	241.379	COMPACT
56	63.000	46.000	39.000	5.500	59178.180	2276.084	0.807	1.397	174.603	COMPACTELONGATED
57	57.000	56.000	55.000	5.500	91923.000	2506.991	0.982	1.027	192.982	COMPACT
58	62.000	60.000	59.000	5.000	114919.438	2921.681	0.978	1.034	161.290	COMPACT
59	56.000	49.000	34.000	6.000	48849.668	2155.132	0.750	1.544	214.286	COMPACTPLATY
60	65.000	45.000	41.000	7.800	62792.582	2297.290	0.831	1.341	240.000	COMPACTELONGATED
61	60.000	50.000	40.000	4.500	62831.852	2356.194	0.811	1.375	150.000	COMPACTBLADED
62	68.000	62.000	30.000	5.000	66224.750	3311.239	0.598	2.167	147.059	PLATY
63	90.000	82.000	71.000	9.500	274355.250	5796.238	0.881	1.211	211.111	COMPACT
64	90.000	89.000	50.000	9.500	209701.250	6291.039	0.678	1.790	211.111	COMPACTPLATY
65	47.000	44.000	42.000	9.000	45477.691	1624.203	0.948	1.083	382.979	COMPACT
66	70.000	69.000	30.000	5.500	75869.438	3793.473	0.571	2.317	157.143	PLATY
67	89.000	75.000	67.000	8.500	234166.438	5242.531	0.876	1.224	191.011	COMPACT
68	85.000	75.000	50.000	8.500	166897.063	5006.910	0.732	1.600	200.000	COMPACTPLATY
69	99.000	83.000	50.000	9.000	215120.500	6453.613	0.673	1.820	181.818	COMPACTPLATY
70	95.000	83.000	58.000	7.000	239457.375	6192.863	0.753	1.534	147.368	COMPACTPLATY
71	95.000	86.000	55.000	9.500	235279.063	6416.699	0.718	1.645	200.000	COMPACTPLATY
72	96.000	94.000	53.000	8.500	250422.625	7087.430	0.678	1.792	177.083	COMPACTPLATY
73	93.000	73.000	60.000	7.000	213282.688	5332.066	0.809	1.383	150.538	COMPACTBLADED
74	99.000	72.000	53.000	8.000	197807.188	5598.316	0.733	1.613	161.616	COMPACTBLADED
75	86.000	74.000	60.000	5.500	199930.938	4998.273	0.827	1.333	127.907	COMPACTBLADED
76	90.000	70.000	50.000	9.000	164933.563	4948.008	0.735	1.600	200.000	COMPACTBLADED
77	93.000	85.000	72.000	8.000	298011.438	6208.570	0.869	1.236	172.043	COMPACT
78	94.000	80.000	50.000	5.500	196873.125	5906.191	0.693	1.740	117.021	COMPACTPLATY
79	98.000	76.000	55.000	6.500	214487.000	5849.645	0.741	1.582	132.653	COMPACTBLADED
80	90.000	70.000	52.000	6.000	171530.938	4948.008	0.754	1.538	133.333	COMPACTBLADED
81	81.000	65.000	55.000	7.500	151621.063	4135.121	0.831	1.327	185.185	COMPACTBLADED
82	96.000	85.000	70.000	7.000	299079.563	6408.848	0.844	1.293	145.833	COMPACT
83	95.000	75.000	45.000	6.500	167878.813	5595.961	0.657	1.889	136.842	BLADED
84	45.000	43.000	38.000	8.000	38500.215	1519.745	0.907	1.158	355.555	COMPACT
85	80.000	63.000	61.000	7.000	160975.188	3958.407	0.904	1.172	175.000	COMPACT
86	90.000	80.000	73.000	8.000	275203.500	5654.863	0.905	1.164	177.778	COMPACT
87	81.000	57.000	50.000	6.000	120872.750	3626.183	0.815	1.380	148.148	COMPACTELONGATED
88	61.000	50.000	30.000	4.000	47909.285	2395.464	0.666	1.850	131.148	BLADED
89	75.000	70.000	32.000	5.000	87964.563	4123.340	0.580	2.266	133.333	PLATY
90	78.000	75.000	33.000	3.500	101080.688	4594.578	0.571	2.318	89.744	PLATY
91	59.000	46.000	35.000	5.000	49736.645	2131.571	0.767	1.500	169.492	COMPACTBLADED
92	62.000	44.000	35.000	5.000	49993.211	2142.566	0.766	1.514	161.290	COMPACTELONGATED
93	60.000	50.000	45.000	7.500	70685.813	2356.194	0.877	1.222	250.000	COMPACT
94	85.000	55.000	30.000	8.000	73434.688	3671.736	0.577	2.333	188.235	BLADED
95	57.000	54.000	30.000	5.500	48349.109	2417.455	0.664	1.850	192.982	COMPACTPLATY
96	55.000	50.000	40.000	7.500	57595.863	2159.845	0.835	1.313	272.727	COMPACT
97	55.000	50.000	25.000	6.000	35997.414	2159.845	0.610	2.100	218.182	PLATY
98	65.000	45.000	44.000	6.000	67387.125	2297.290	0.871	1.250	184.615	COMPACTELONGATED
99	65.000	55.000	35.000	9.500	65515.293	2807.798	0.700	1.714	292.308	COMPACTBLADED
100	65.000	60.000	40.000	8.000	81681.375	3063.053	0.743	1.563	246.154	COMPACTPLATY

Table 95 Shape measurements of pebbles

(II-146)

FAN ONE SITE THREE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	45.000	34.000	20.000	7.000	16022.121	1201.659	0.639	1.975	311.111		BLADED
2	48.000	18.000	15.000	6.000	6785.840	678.584	0.639	2.200	250.000	VERY	ELONGATED
3	25.000	16.000	12.000	3.000	2513.274	314.159	0.711	1.708	240.000		ELONGATED
4	40.000	26.000	17.000	6.000	9257.223	816.814	0.653	1.941	300.000		BLADED
5	45.000	30.000	12.000	3.000	8482.297	1060.287	0.474	3.125	133.333	VERY	BLADED
6	40.000	25.000	18.000	4.000	9424.777	785.398	0.687	1.806	200.000		ELONGATED
7	33.000	22.000	13.000	4.500	4941.723	570.199	0.615	2.115	272.727		BLADED
8	45.000	28.000	19.000	4.000	12534.953	989.602	0.659	1.921	177.778		BLADED
9	37.000	30.000	18.000	6.000	10461.500	871.792	0.663	1.861	324.324		BLADED
10	40.000	25.000	17.000	5.000	8901.176	785.398	0.661	1.912	250.000		BLADED
11	35.000	24.000	21.000	6.000	9236.281	659.734	0.807	1.405	342.857	COMPACT	ELONGATED
12	27.000	20.000	16.000	2.000	4523.891	424.115	0.780	1.469	148.148	COMPACT	BLADED
13	41.000	25.000	10.000	3.500	5366.887	805.033	0.460	3.300	170.732	VERY	BLADED
14	33.000	17.000	10.000	2.000	2937.389	440.608	0.563	2.500	121.212	VERY	ELONGATED
15	26.000	25.000	24.000	8.500	8168.141	510.509	0.961	1.063	653.846	COMPACT	
16	65.000	35.000	26.000	6.000	30970.867	1786.781	0.667	1.923	184.615		ELONGATED
17	40.000	35.000	25.000	6.000	18325.957	1099.557	0.764	1.500	300.000	COMPACT	BLADED
18	57.000	40.000	23.000	4.000	27457.520	1790.708	0.614	2.109	140.351		BLADED
19	65.000	43.000	32.000	4.000	46830.672	2195.188	0.716	1.688	123.077		ELONGATED
20	57.000	35.000	27.000	5.000	28203.645	1566.869	0.715	1.704	175.439		ELONGATED
21	50.000	35.000	19.000	4.500	17409.656	1374.447	0.591	2.237	180.000		BLADED
22	55.000	45.000	23.000	6.000	29805.859	1943.860	0.598	2.174	218.182		PLATY
23	33.000	20.000	13.000	4.000	4492.477	518.363	0.635	2.038	242.424		BLADED
24	60.000	45.000	25.000	5.000	35342.914	2120.575	0.614	2.100	166.667		BLADED
25	45.000	35.000	20.000	6.000	16493.359	1237.002	0.633	2.000	266.667		BLADED
26	65.000	40.000	21.000	8.000	28588.492	2042.035	0.554	2.500	246.154	VERY	BLADED
27	45.000	25.000	25.000	4.500	14726.215	883.573	0.822	1.400	200.000	COMPACT	ELONGATED
28	52.000	35.000	17.000	6.500	16200.145	1429.425	0.542	2.559	250.000	VERY	BLADED
29	52.000	40.000	12.000	5.000	13069.023	1633.628	0.411	3.833	192.308	VERY	PLATY
30	35.000	16.000	10.000	3.000	2932.153	439.823	0.563	2.550	171.429	VERY	ELONGATED
31	65.000	51.000	24.000	6.000	41657.516	2603.595	0.558	2.417	184.615		BLADED
32	55.000	30.000	14.000	6.000	12095.129	1295.907	0.492	3.036	218.182	VERY	BLADED
33	55.000	50.000	11.000	7.000	15838.859	2159.845	0.353	4.773	254.545	VERY	PLATY
34	60.000	40.000	18.000	5.500	22619.465	1884.956	0.513	2.778	183.333	VERY	BLADED
35	67.000	60.000	34.000	5.000	71565.438	3157.301	0.660	1.868	149.254	COMPACT	PLATY
36	60.000	45.000	22.000	7.000	31101.766	2120.575	0.564	2.386	233.333		BLADED
37	50.000	43.000	19.000	6.000	21389.008	1688.606	0.552	2.447	240.000		PLATY
38	48.000	24.000	20.000	5.500	12063.715	904.779	0.703	1.800	229.167		ELONGATED
39	45.000	40.000	14.000	5.000	13194.688	1413.717	0.478	3.036	222.222	VERY	PLATY
40	55.000	50.000	25.000	7.500	35997.414	2159.845	0.610	2.100	272.727		PLATY
41	55.000	40.000	24.000	5.000	27646.012	1727.876	0.640	1.979	181.818		BLADED
42	36.000	26.000	18.000	6.500	8821.590	735.133	0.702	1.722	361.111		BLADED
43	45.000	22.000	15.000	4.000	7775.441	777.544	0.610	2.233	177.778	VERY	ELONGATED
44	60.000	35.000	27.000	7.000	29688.047	1649.336	0.703	1.759	233.333		ELONGATED
45	66.000	40.000	26.000	8.500	35939.816	2073.451	0.635	2.038	257.576		BLADED
46	46.000	40.000	31.000	9.000	29866.070	1445.133	0.805	1.387	391.304	COMPACT	BLADED
47	46.000	25.000	24.000	5.500	14451.324	903.208	0.794	1.479	239.130	COMPACT	ELONGATED
48	65.000	30.000	24.000	8.000	24504.422	1531.526	0.666	1.979	246.154		ELONGATED
49	65.000	30.000	24.000	5.500	24504.422	1531.526	0.666	1.979	169.231		ELONGATED
50	60.000	38.000	24.000	6.000	28651.324	1790.708	0.632	2.042	200.000		BLADED
51	50.000	35.000	15.000	9.500	13744.465	1374.447	0.505	2.833	380.000	VERY	BLADED
52	60.000	55.000	26.000	7.000	44924.773	2591.814	0.589	2.212	233.333		PLATY
53	60.000	40.000	24.000	6.500	30159.289	1884.956	0.621	2.083	216.667		BLADED
54	65.000	45.000	19.000	6.000	29099.000	2297.290	0.498	2.895	184.615	VERY	BLADED
55	65.000	45.000	11.000	5.500	16846.789	2297.290	0.346	5.000	169.231	VERY	BLADED
56	46.000	45.000	22.000	8.000	23844.688	1625.774	0.616	2.068	347.826		PLATY
57	50.000	48.000	13.000	7.000	16336.281	1884.956	0.413	3.769	280.000	VERY	PLATY
58	60.000	50.000	30.000	5.000	47123.887	2356.194	0.669	1.833	166.667		BLADED
59	51.000	36.000	15.000	7.500	14419.910	1441.991	0.497	2.900	294.117	VERY	BLADED
60	42.000	38.000	19.000	8.000	15877.605	1253.495	0.609	2.105	380.952		PLATY
61	47.000	36.000	14.000	5.500	12403.004	1328.894	0.487	2.964	234.043	VERY	BLADED
62	65.000	30.000	24.000	6.000	24504.422	1531.526	0.666	1.979	184.615		ELONGATED
63	53.000	31.000	21.000	7.000	18065.727	1290.409	0.645	2.000	264.151		ELONGATED
64	45.000	26.000	20.000	8.000	12252.211	918.916	0.699	1.775	355.555		ELONGATED
65	53.000	23.000	19.000	3.000	12127.070	957.400	0.667	2.000	113.208		ELONGATED
66	50.000	38.000	22.000	6.000	21886.426	1492.256	0.634	2.000	240.000		BLADED
67	26.000	22.000	15.000	6.000	4492.477	449.248	0.733	1.600	461.538	COMPACT	BLADED
68	50.000	24.000	18.000	4.500	11309.730	942.478	0.646	2.056	180.000		ELONGATED
69	30.000	22.000	17.000	5.000	5874.777	518.363	0.759	1.529	333.333	COMPACT	BLADED
70	35.000	20.000	10.000	5.000	3665.191	549.779	0.523	2.750	285.714	VERY	BLADED
71	50.000	36.000	10.000	4.500	9424.777	1413.717	0.382	4.300	180.000	VERY	BLADED
72	35.000	25.000	20.000	6.000	9162.977	687.223	0.770	1.500	342.857	COMPACT	ELONGATED
73	40.000	30.000	11.000	4.000	6911.500	942.478	0.465	3.182	200.000	VERY	BLADED
74	38.000	29.000	22.000	5.500	12694.125	865.509	0.760	1.523	289.474	COMPACT	BLADED
75	67.000	40.000	18.000	5.000	25258.402	2104.867	0.494	2.972	149.254	VERY	BLADED
76	35.000	31.000	16.000	9.500	9089.672	852.157	0.618	2.063	542.857		PLATY
77	46.000	40.000	13.000	5.500	12524.480	1445.133	0.451	3.308	239.130	VERY	PLATY
78	27.000	21.000	18.000	2.500	5343.848	445.321	0.830	1.333	185.185	COMPACT	ELONGATED
79	28.000	23.000	11.000	6.000	3709.174	505.796	0.573	2.318	428.571		PLATY
80	50.000	30.000	25.000	8.000	19634.953	1178.097	0.747	1.600	320.000		ELONGATED
81	45.000	36.000	21.000	8.000	17812.828	1272.345	0.648	1.929	355.555		BLADED
82	65.000	50.000	53.000	7.000	90189.875	2552.544	0.953	1.085	215.385	COMPACT	
83	60.000	50.000	33.000	9.000	51836.277	2356.194	0.713	1.667	300.000	COMPACT	BLADED
84	60.000	50.000	21.000	8.000	32986.723	2356.194	0.528	2.619	266.667		PLATY
85	62.000	45.000	19.000	3.000	27755.969	2191.261	0.506	2.816	96.774	VERY	BLADED
86	32.000	22.000	12.000	3.500	4423.359	552.920	0.589	2.250	218.750		BLADED
87	36.000	21.000	19.000	5.000	7520.973	593.761	0.782	1.500	277.778	COMPACT	ELONGATED
88	52.000	36.000	21.000	6.000	20583.715	1470.265	0.618	2.095	230.769		BLADED
89	60.000	40.000	23.000	8.000	28902.652	1884.956	0.604	2.174	266.667		BLADED
90	41.000	40.000	28.000	9.000	24043.652	1288.053	0.782	1.446	439.024	COMPACT	PLATY
91	42.000	40.000	11.000	8.000	9676.102	1319.469	0.416	3.727	380.952	VERY	PLATY
92	55.000	30.000	27.000	8.000	23326.324	1295.907	0.762	1.574	290.909		ELONGATED
93	47.000	25.000	17.000	4.000	10458.883	922.843	0.627	2.118	170.213		ELONGATED
94	40.000	26.000	13.000	6.000	7079.055	816.814	0.546	2.538	300.000	VERY	BLADED
95	31.000	20.000	18.000	5.000	5843.359	486.947	0.805	1.417	322.581	COMPACT	ELONGATED
96	31.000	25.000	11.000	4.000	4463.676	608.683	0.538	2.545	258.064		PLATY
97	26.000	24.000	14.000	6.500	4574.156	490.088	0.680	1.786	500.000	COMPACT	PLATY
98	40.000	35.000	25.000	5.000	18325.957	1099.557	0.764	1.500	250.000	COMPACT	BLADED
99	55.000	33.000	12.000	4.000	11403.980	1425.498	0.430	3.667	145.455	VERY	BLADED
100	50.000	30.000	12.000	3.500	9424.777	1178.097	0.458	3.333	140.000	VERY	BLADED

Table 96 Shape measurements of pebbles

FAN ONE SITE FOUR (II-147)

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	90.000	70.000	55.000	9.800	181426.938	4948.008	0.783	1.455	217.778	COMPACT	BLADED
2	90.000	85.000	55.000	8.000	220304.125	6008.293	0.734	1.591	177.778	COMPACT	PLATY
3	50.000	40.000	20.000	9.000	20943.949	1570.796	0.585	2.250	360.000		BLADED
4	80.000	50.000	35.000	6.500	73303.813	3141.593	0.674	1.857	162.500		ELONGATED
5	80.000	54.000	52.000	8.500	117621.188	3392.920	0.855	1.288	212.500	COMPACT	ELONGATED
6	60.000	50.000	33.000	4.500	51836.277	2356.194	0.713	1.667	150.000	COMPACT	BLADED
7	66.000	60.000	40.000	4.500	82938.000	3110.177	0.739	1.575	136.364	COMPACT	PLATY
8	45.000	40.000	30.000	9.500	28274.332	1413.717	0.794	1.417	422.222	COMPACT	BLADED
9	50.000	47.000	42.000	8.500	51679.195	1845.686	0.909	1.155	340.000	COMPACT	
10	65.000	55.000	40.000	5.000	74874.563	2807.798	0.765	1.500	153.846	COMPACT	BLADED
11	56.000	40.000	35.000	5.500	41050.141	1759.292	0.818	1.371	196.429	COMPACT	ELONGATED
12	47.000	37.000	32.000	6.500	29137.223	1365.807	0.838	1.313	276.596	COMPACT	ELONGATED
13	60.000	54.000	30.000	5.000	50893.801	2544.690	0.652	1.900	166.667		PLATY
14	97.000	87.000	57.000	3.500	251863.000	6627.973	0.727	1.614	72.165	COMPACT	PLATY
15	52.000	40.000	28.000	6.500	30494.391	1633.628	0.722	1.643	250.000	COMPACT	BLADED
16	50.000	40.000	37.000	6.500	38746.309	1570.796	0.881	1.216	260.000	COMPACT	
17	50.000	45.000	30.000	9.000	35342.914	1767.146	0.737	1.583	360.000	COMPACT	PLATY
18	40.000	30.000	20.000	6.000	12566.367	942.478	0.693	1.750	300.000		BLADED
19	41.000	38.000	35.000	6.500	28551.840	1223.650	0.923	1.129	317.073	COMPACT	
20	45.000	40.000	32.000	3.500	30159.289	1413.717	0.829	1.328	155.556	COMPACT	
21	44.000	36.000	32.000	6.500	26540.172	1244.071	0.865	1.250	295.454	COMPACT	
22	56.000	55.000	45.000	3.000	72570.750	2419.026	0.870	1.233	107.143	COMPACT	
23	56.000	43.000	41.000	4.000	51693.859	1891.239	0.887	1.207	142.857	COMPACT	
24	42.000	35.000	25.000	5.500	19242.254	1154.535	0.752	1.540	261.905	COMPACT	BLADED
25	65.000	55.000	40.000	2.500	74874.563	2807.798	0.765	1.500	76.923	COMPACT	BLADED
26	50.000	48.000	27.000	7.500	33929.199	1884.956	0.672	1.815	300.000	COMPACT	PLATY
27	46.000	37.000	30.000	6.500	26734.953	1336.748	0.809	1.383	282.609	COMPACT	BLADED
28	50.000	45.000	35.000	6.000	41233.402	1767.146	0.817	1.357	240.000	COMPACT	
29	50.000	40.000	28.000	5.000	29321.531	1570.796	0.732	1.607	200.000	COMPACT	BLADED
30	50.000	40.000	30.000	9.500	31415.926	1570.796	0.766	1.500	380.000	COMPACT	BLADED
31	58.000	49.000	39.000	6.500	58034.641	2232.102	0.812	1.372	224.138	COMPACT	BLADED
32	47.000	45.000	30.000	5.000	33222.340	1661.117	0.752	1.533	212.766	COMPACT	PLATY
33	43.000	42.000	14.000	2.500	13238.668	1418.429	0.477	3.036	116.279	VERY	PLATY
34	46.000	29.000	20.000	3.000	13969.613	1047.721	0.669	1.875	130.435		BLADED
35	45.000	43.000	30.000	3.500	30394.906	1519.745	0.775	1.467	155.556	COMPACT	PLATY
36	45.000	41.000	27.000	3.500	26083.070	1449.060	0.734	1.593	155.556	COMPACT	PLATY
37	49.000	44.000	32.000	5.500	36124.125	1693.318	0.780	1.453	224.490	COMPACT	PLATY
38	60.000	50.000	26.000	2.000	40840.703	2356.194	0.609	2.115	66.667		PLATY
39	50.000	40.000	35.000	9.000	36651.914	1570.796	0.849	1.286	360.000	COMPACT	
40	65.000	50.000	42.000	4.000	71471.188	2552.544	0.816	1.369	123.077	COMPACT	BLADED
41	55.000	50.000	35.000	5.500	50396.379	2159.845	0.764	1.500	200.000	COMPACT	PLATY
42	47.000	45.000	26.000	3.500	28792.695	1661.117	0.684	1.769	148.936	COMPACT	PLATY
43	50.000	40.000	35.000	6.000	36651.914	1570.796	0.849	1.286	240.000	COMPACT	
44	46.000	43.000	24.000	5.000	24856.277	1553.517	0.663	1.854	217.391	COMPACT	PLATY
45	61.000	56.000	20.000	5.500	35772.266	2682.920	0.489	2.925	180.328	VERY	PLATY
46	68.000	65.000	55.000	8.000	127286.813	3471.460	0.881	1.209	235.294	COMPACT	
47	45.000	44.000	20.000	7.000	20734.508	1555.088	0.587	2.225	311.111		PLATY
48	65.000	45.000	40.000	8.500	61261.055	2297.290	0.818	1.375	261.538	COMPACT	ELONGATED
49	50.000	34.000	31.000	7.500	27593.652	1335.177	0.827	1.355	300.000	COMPACT	ELONGATED
50	52.000	50.000	21.000	5.500	28588.492	2042.035	0.554	2.429	211.538		PLATY
51	47.000	45.000	27.000	7.500	29900.105	1661.117	0.701	1.704	319.149	COMPACT	PLATY
52	37.000	35.000	24.000	4.500	16273.449	1017.091	0.763	1.500	243.243	COMPACT	PLATY
53	45.000	40.000	38.000	8.500	35814.156	1413.717	0.929	1.118	377.778	COMPACT	
54	48.000	30.000	27.000	5.400	20357.520	1130.973	0.797	1.444	225.000	COMPACT	ELONGATED
55	50.000	45.000	30.000	3.500	35342.914	1767.146	0.737	1.583	140.000	COMPACT	PLATY
56	44.000	39.000	33.000	9.500	29650.348	1347.743	0.859	1.258	431.818	COMPACT	
57	45.000	43.000	41.000	9.500	41539.707	1519.745	0.954	1.073	422.222	COMPACT	
58	41.000	35.000	33.000	9.000	24795.020	1127.046	0.912	1.152	439.024	COMPACT	
59	40.000	29.000	28.000	4.500	17006.484	911.062	0.878	1.232	225.000	COMPACT	
60	38.000	31.000	26.000	7.000	16036.781	925.199	0.831	1.327	368.421	COMPACT	BLADED
61	66.000	64.000	36.000	8.500	79620.500	3317.522	0.674	1.806	257.576	COMPACT	PLATY
62	41.000	30.000	27.000	3.500	17388.715	966.040	0.840	1.315	170.732	COMPACT	ELONGATED
63	70.000	65.000	25.000	9.000	59559.359	3573.562	0.516	2.700	257.143		PLATY
64	39.000	30.000	24.000	6.000	14702.652	918.916	0.790	1.438	307.692	COMPACT	BLADED
65	85.000	50.000	40.000	9.500	89011.750	3337.942	0.722	1.688	223.529		ELONGATED
66	39.000	30.000	25.000	7.500	15315.262	918.916	0.811	1.380	384.615	COMPACT	BLADED
67	43.000	37.000	35.000	7.500	29156.598	1249.568	0.917	1.143	348.837	COMPACT	
68	41.000	35.000	26.000	5.000	19535.469	1127.046	0.778	1.462	243.902	COMPACT	BLADED
69	40.000	30.000	24.000	6.500	15079.645	942.478	0.783	1.458	325.000	COMPACT	BLADED
70	40.000	35.000	30.000	9.500	21991.148	1099.557	0.863	1.250	475.000	COMPACT	
71	48.000	35.000	30.000	7.000	26389.375	1319.469	0.812	1.383	291.667	COMPACT	ELONGATED
72	40.000	38.000	12.000	5.500	9550.441	1193.805	0.456	3.250	275.000	VERY	PLATY
73	40.000	39.000	37.000	8.500	30222.121	1225.221	0.957	1.068	425.000	COMPACT	
74	45.000	38.000	20.000	6.500	17907.078	1343.031	0.616	2.075	288.889		PLATY
75	36.000	26.000	24.000	3.500	11762.121	735.133	0.851	1.292	194.444	COMPACT	ELONGATED
76	30.000	25.000	20.000	2.500	7853.980	589.049	0.811	1.375	166.667	COMPACT	BLADED
77	43.000	39.000	31.000	6.500	27220.328	1317.113	0.831	1.323	302.325	COMPACT	
78	45.000	32.000	30.000	7.000	22619.465	1130.973	0.855	1.283	311.111	COMPACT	ELONGATED
79	35.000	31.000	20.000	4.500	11362.090	852.157	0.717	1.650	257.143	COMPACT	PLATY
80	45.000	37.000	32.000	7.500	27897.340	1307.688	0.850	1.281	333.333	COMPACT	
81	37.000	30.000	25.000	5.000	14529.863	871.792	0.826	1.340	270.270	COMPACT	BLADED
82	38.000	32.000	25.000	4.500	15917.402	955.044	0.801	1.400	236.842	COMPACT	BLADED
83	42.000	28.000	27.000	3.500	16625.305	923.628	0.853	1.296	166.667	COMPACT	ELONGATED
84	45.000	40.000	34.000	8.500	32044.242	1413.717	0.863	1.250	377.778	COMPACT	
85	52.000	40.000	35.000	9.000	38117.988	1633.628	0.838	1.314	346.154	COMPACT	ELONGATED
86	46.000	40.000	30.000	8.500	28902.652	1445.133	0.788	1.433	369.565	COMPACT	BLADED
87	50.000	45.000	40.000	5.500	47123.887	1767.146	0.893	1.188	220.000	COMPACT	
88	50.000	42.000	35.000	3.500	38484.508	1649.336	0.836	1.314	140.000	COMPACT	
89	30.000	25.000	20.000	2.500	7853.980	589.049	0.811	1.375	166.667	COMPACT	BLADED
90	33.000	30.000	15.000	4.500	7775.441	777.544	0.610	2.100	272.727		PLATY
91	33.000	31.000	15.000	3.500	8034.621	803.462	0.604	2.133	212.121		PLATY
92	30.000	20.000	11.000	2.500	3455.752	471.239	0.586	2.273	166.667		BLADED
93	30.000	29.000	16.000	3.000	7288.492	683.296	0.665	1.844	200.000	COMPACT	PLATY
94	33.000	25.000	20.000	3.500	8639.379	647.953	0.786	1.450	212.121	COMPACT	BLADED
95	35.000	32.000	16.000	4.000	9382.887	879.646	0.611	2.094	228.571		PLATY
96	35.000	30.000	25.000	6.500	13744.465	824.668	0.841	1.300	371.428	COMPACT	
97	36.000	26.000	25.000	2.000	12252.211	735.133	0.874	1.240	111.111	COMPACT	ELONGATED
98	35.000	27.000	22.000	4.500	10885.617	742.201	0.800	1.409	257.143	COMPACT	BLADED
99	30.000	25.000	15.000	7.500	5890.484	589.049	0.669	1.833	500.000		BLADED
100	32.000	30.000	28.000	8.000	14074.332	753.982	0.935	1.107	500.000	COMPACT	

Table 97 Shape measurements of pebbles

FAN ONE SITE FIVE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	50.000	40.000	25.000	5.500	26179.938	1570.796	0.679	1.800	220.000		BLADED
2	43.000	36.000	31.000	2.000	25126.457	1215.796	0.853	1.274	93.023	COMPACT	
3	40.000	36.000	19.000	7.000	14325.660	1130.973	0.631	2.000	350.000		PLATY
4	44.000	42.000	27.000	9.500	26125.484	1451.416	0.733	1.593	431.818	COMPACT	PLATY
5	41.000	39.000	20.000	5.500	16744.688	1255.852	0.630	2.000	268.292		PLATY
6	45.000	42.000	17.000	2.500	16823.227	1484.402	0.535	2.559	111.111		PLATY
7	50.000	42.000	20.000	4.000	21991.148	1649.336	0.575	2.300	160.000		PLATY
8	60.000	50.000	40.000	6.500	62831.852	2356.194	0.811	1.375	216.667	COMPACT	BLADED
9	50.000	40.000	30.000	3.500	31415.926	1570.796	0.766	1.500	140.000	COMPACT	BLADED
10	33.000	25.000	22.000	4.500	9503.316	647.953	0.837	1.318	272.727	COMPACT	ELONGATED
11	35.000	30.000	24.000	6.000	13194.688	824.668	0.819	1.354	342.857	COMPACT	BLADED
12	32.000	29.000	23.000	7.000	11175.691	728.849	0.829	1.326	437.500	COMPACT	
13	40.000	31.000	27.000	6.000	17530.086	973.894	0.838	1.315	300.000	COMPACT	ELONGATED
14	32.000	26.000	22.000	6.500	9583.949	653.451	0.835	1.318	406.250	COMPACT	BLADED
15	40.000	34.000	31.000	9.500	22074.922	1068.141	0.891	1.194	475.000	COMPACT	
16	42.000	37.000	19.000	2.000	15459.777	1220.509	0.615	2.079	95.238		PLATY
17	35.000	31.000	15.000	3.500	8521.566	852.157	0.592	2.200	200.000		PLATY
18	35.000	31.000	15.000	3.500	8521.566	852.157	0.592	2.200	200.000		PLATY
19	30.000	29.000	26.000	7.500	11843.801	683.296	0.919	1.135	500.000	COMPACT	
20	40.000	38.000	15.000	2.500	11938.051	1193.805	0.529	2.600	125.000		PLATY
21	42.000	38.000	28.000	9.500	23398.582	1253.495	0.789	1.429	452.381	COMPACT	PLATY
22	42.000	35.000	27.000	3.000	20781.633	1154.535	0.792	1.426	142.857	COMPACT	BLADED
23	37.000	32.000	27.000	2.500	16738.402	929.911	0.851	1.278	135.135	COMPACT	
24	28.000	26.000	23.000	6.000	8767.137	571.770	0.899	1.174	428.571	COMPACT	
25	40.000	33.000	30.000	5.000	20734.508	1036.725	0.880	1.217	250.000	COMPACT	
26	30.000	26.000	21.000	4.500	8576.547	612.610	0.827	1.333	300.000	COMPACT	
27	30.000	29.000	28.000	5.000	12754.863	683.296	0.966	1.054	333.333	COMPACT	
28	37.000	35.000	25.000	6.500	16951.508	1017.091	0.784	1.440	351.351	COMPACT	PLATY
29	31.000	27.000	17.000	6.500	7450.285	657.378	0.702	1.706	419.355	COMPACT	PLATY
30	42.000	31.000	20.000	3.500	13634.512	1022.588	0.675	1.825	166.667		BLADED
31	34.000	27.000	20.000	3.000	9613.273	720.995	0.758	1.525	176.471	COMPACT	BLADED
32	40.000	37.000	22.000	6.500	17048.375	1162.389	0.689	1.750	325.000	COMPACT	PLATY
33	32.000	31.000	30.000	9.000	15582.297	779.115	0.968	1.050	562.500	COMPACT	
34	40.000	39.000	25.000	7.000	20420.352	1225.221	0.737	1.580	350.000	COMPACT	PLATY
35	30.000	28.000	22.000	8.500	9676.102	659.734	0.832	1.318	566.667	COMPACT	
36	40.000	35.000	18.000	8.000	13194.688	1099.557	0.614	2.083	400.000		PLATY
37	40.000	36.000	18.000	2.500	13571.680	1130.973	0.608	2.111	125.000		PLATY
38	28.000	27.000	26.000	9.500	10291.855	593.761	0.963	1.058	678.571	COMPACT	
39	24.000	20.000	17.000	9.000	4272.563	376.991	0.844	1.294	750.000	COMPACT	
40	42.000	31.000	28.000	3.500	19088.316	1022.588	0.844	1.304	166.667	COMPACT	ELONGATED
41	32.000	27.000	17.000	5.000	7690.617	678.584	0.694	1.735	312.500	COMPACT	BLADED
42	36.000	30.000	25.000	7.500	14137.164	848.230	0.833	1.320	416.667	COMPACT	BLADED
43	30.000	25.000	23.000	5.500	9032.078	589.049	0.890	1.196	366.667	COMPACT	
44	36.000	31.000	11.000	4.000	6427.695	876.504	0.477	3.045	222.222	VERY	PLATY
45	34.000	28.000	20.000	5.000	9969.320	747.699	0.749	1.550	294.117	COMPACT	BLADED
46	37.000	33.000	27.000	7.000	17261.480	958.971	0.842	1.296	378.378	COMPACT	
47	40.000	33.000	25.000	6.500	17278.758	1036.725	0.779	1.460	325.000	COMPACT	BLADED
48	36.000	34.000	31.000	9.000	19867.430	961.327	0.923	1.129	500.000	COMPACT	
49	40.000	33.000	22.000	8.000	15205.305	1036.725	0.716	1.659	400.000	COMPACT	BLADED
50	30.000	24.000	20.000	5.500	7539.820	565.487	0.822	1.350	366.667	COMPACT	BLADED
51	35.000	31.000	17.000	3.500	9657.777	852.157	0.643	1.941	200.000		PLATY
52	40.000	38.000	20.000	3.500	15917.402	1193.805	0.641	1.950	175.000		PLATY
53	45.000	38.000	25.000	6.500	22383.848	1343.031	0.715	1.660	288.889	COMPACT	BLADED
54	41.000	40.000	23.000	7.500	19750.145	1288.053	0.686	1.761	365.854	COMPACT	PLATY
55	38.000	31.000	30.000	9.500	18503.980	925.199	0.914	1.150	500.000	COMPACT	
56	36.000	32.000	19.000	5.000	11460.527	904.779	0.679	1.789	277.778	COMPACT	PLATY
57	35.000	24.000	21.000	9.000	9236.281	659.734	0.807	1.405	514.286	COMPACT	ELONGATED
58	31.000	30.000	18.000	4.500	8765.043	730.420	0.704	1.694	290.323	COMPACT	PLATY
59	45.000	37.000	17.000	6.500	14820.461	1307.688	0.558	2.412	288.889		PLATY
60	30.000	23.000	20.000	7.500	7225.660	541.925	0.834	1.325	500.000	COMPACT	ELONGATED
61	36.000	34.000	19.000	5.500	12176.813	961.327	0.666	1.842	305.555	COMPACT	PLATY
62	37.000	36.000	30.000	7.500	20923.004	1046.150	0.877	1.217	405.405	COMPACT	
63	35.000	30.000	28.000	5.400	15393.801	824.668	0.907	1.161	308.571	COMPACT	
64	43.000	32.000	30.000	3.500	21614.156	1080.708	0.868	1.250	162.791	COMPACT	ELONGATED
65	30.000	25.000	17.000	5.000	6675.883	589.049	0.728	1.618	333.333	COMPACT	BLADED
66	37.000	30.000	16.000	2.500	9299.113	871.792	0.613	2.094	135.135		BLADED
67	40.000	35.000	25.000	6.000	18325.957	1099.557	0.764	1.500	300.000	COMPACT	BLADED
68	35.000	32.000	20.000	6.500	11728.609	879.646	0.709	1.675	371.428	COMPACT	PLATY
69	36.000	26.000	23.000	7.500	11272.031	735.133	0.827	1.348	416.667	COMPACT	ELONGATED
70	40.000	37.000	13.000	9.000	10074.039	1162.389	0.485	2.962	450.000	VERY	PLATY
71	38.000	30.000	26.000	4.500	15519.465	895.354	0.840	1.308	236.842	COMPACT	ELONGATED
72	35.000	32.000	31.000	8.500	18179.348	879.646	0.950	1.081	485.714	COMPACT	
73	30.000	23.000	20.000	2.500	7225.660	541.925	0.834	1.325	166.667	COMPACT	ELONGATED
74	30.000	25.000	19.000	5.500	7461.281	589.049	0.784	1.447	366.667	COMPACT	BLADED
75	37.000	35.000	20.000	3.500	13561.207	1017.091	0.676	1.800	189.189	COMPACT	PLATY
76	43.000	36.000	30.000	7.000	24315.926	1215.796	0.835	1.317	325.581	COMPACT	BLADED
77	40.000	36.000	25.000	6.000	18849.555	1130.973	0.757	1.520	300.000	COMPACT	PLATY
78	30.000	26.000	19.000	3.500	7759.730	612.610	0.774	1.474	233.333	COMPACT	BLADED
79	40.000	30.000	29.000	9.500	18221.234	942.478	0.888	1.207	475.000	COMPACT	
80	34.000	32.000	14.000	2.500	7975.453	854.513	0.565	2.357	147.059		PLATY
81	30.000	24.000	23.000	7.500	8670.793	565.487	0.902	1.174	500.000	COMPACT	
82	42.000	38.000	30.000	5.500	25069.906	1253.495	0.826	1.333	261.905	COMPACT	
83	30.000	34.000	25.000	3.400	13351.766	801.106	0.849	1.280	226.667	COMPACT	
84	42.000	32.000	30.000	9.000	21111.500	1055.575	0.875	1.233	428.571	COMPACT	
85	40.000	27.000	16.000	5.500	9047.785	848.230	0.619	2.094	275.000		BLADED
86	43.000	40.000	30.000	6.000	27017.695	1350.885	0.806	1.383	279.070	COMPACT	PLATY
87	32.000	30.000	25.000	6.500	12566.367	753.982	0.867	1.240	406.250	COMPACT	
88	45.000	35.000	25.000	4.500	20616.699	1237.002	0.735	1.600	200.000	COMPACT	BLADED
89	27.000	24.000	21.000	8.000	7125.129	508.938	0.880	1.214	592.593	COMPACT	
90	35.000	30.000	29.000	4.000	15943.582	824.668	0.929	1.121	228.571	COMPACT	
91	25.000	23.000	19.000	5.500	5720.316	451.604	0.856	1.263	440.000	COMPACT	
92	30.000	27.000	23.000	3.500	9754.645	636.172	0.868	1.239	233.333	COMPACT	
93	30.000	27.000	25.000	7.500	10602.875	636.172	0.917	1.140	500.000	COMPACT	
94	29.000	28.000	27.000	8.500	11479.379	637.743	0.965	1.056	586.207	COMPACT	
95	25.000	22.000	20.000	8.500	5759.586	431.969	0.899	1.175	680.000	COMPACT	
96	29.000	20.000	19.000	9.500	5770.055	455.531	0.854	1.289	655.172	COMPACT	ELONGATED
97	30.000	26.000	14.000	9.500	5717.695	612.610	0.631	2.000	633.333		PLATY
98	30.000	25.000	21.000	7.000	8246.680	589.049	0.838	1.310	466.667	COMPACT	
99	27.000	26.000	25.000	8.000	9189.156	551.349	0.962	1.060	592.593	COMPACT	
100	26.000	25.000	23.000	9.500	7827.801	510.509	0.934	1.109	730.769	COMPACT	

Table 98 Shape measurements of pebbles

FAN TWO SITE ONE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	96.000	55.000	30.000	8.000	82938.000	4146.898	0.554	2.517	166.667	VERY	BLADED
2	75.000	40.000	19.000	6.000	29845.129	2356.194	0.494	3.026	160.000	VERY	BLADED
3	39.000	29.000	22.000	5.500	13028.184	888.285	0.754	1.545	282.051	COMPACT	BLADED
4	62.000	54.000	19.000	5.000	33307.164	2629.513	0.476	3.053	161.290	VERY	PLATY
5	70.000	63.000	37.000	7.000	85435.563	3463.606	0.677	1.797	200.000	COMPACT	PLATY
6	53.000	41.000	26.000	7.000	29582.281	1706.670	0.678	1.808	264.151		BLADED
7	54.000	38.000	24.000	9.500	25786.191	1611.637	0.655	1.917	351.852		BLADED
8	51.000	40.000	24.000	6.000	25635.395	1602.212	0.656	1.896	235.294		BLADED
9	90.000	55.000	18.000	6.000	46652.648	3887.721	0.403	4.028	133.333	VERY	BLADED
10	55.000	50.000	36.000	7.000	51836.277	2159.845	0.778	1.458	254.545	COMPACT	PLATY
11	65.000	45.000	14.000	5.000	21441.367	2297.290	0.406	3.929	153.846	VERY	BLADED
12	55.000	50.000	29.000	4.500	41757.000	2159.845	0.674	1.810	163.636	COMPACT	PLATY
13	67.000	42.000	30.000	6.000	44202.207	2210.110	0.684	1.817	179.104		ELONGATED
14	48.000	38.000	13.000	8.000	12415.570	1432.566	0.453	3.308	333.333	VERY	PLATY
15	78.000	40.000	17.000	5.000	27771.676	2450.442	0.452	3.471	128.205	VERY	BLADED
16	68.000	51.000	12.000	6.000	21790.086	2723.761	0.346	4.958	176.471	VERY	PLATY
17	61.000	51.000	17.000	6.500	27691.566	2443.374	0.453	3.294	213.115	VERY	PLATY
18	73.000	38.000	28.000	6.500	40668.961	2178.694	0.656	1.982	178.082		ELONGATED
19	62.000	54.000	25.000	9.500	43825.215	2629.513	0.572	2.320	306.451		PLATY
20	68.000	50.000	32.000	9.000	56967.543	2670.354	0.670	1.844	264.706		BLADED
21	70.000	56.000	17.000	6.000	34892.621	3078.761	0.419	3.706	171.429	VERY	PLATY
22	56.000	31.000	22.000	4.500	19997.281	1363.451	0.653	1.977	160.714		ELONGATED
23	67.000	35.000	24.000	7.500	29468.137	1841.759	0.626	2.125	223.881		ELONGATED
24	70.000	49.000	26.000	6.500	46694.535	2693.916	0.582	2.288	185.714		BLADED
25	52.000	34.000	32.000	9.000	29623.121	1388.584	0.834	1.344	346.154	COMPACT	ELONGATED
26	53.000	47.000	10.000	4.000	13042.844	1956.427	0.342	5.000	150.943	VERY	PLATY
27	60.000	45.000	24.000	5.000	33929.199	2120.575	0.598	2.188	166.667		BLADED
28	48.000	27.000	20.000	5.500	13571.680	1017.876	0.676	1.875	229.167		ELONGATED
29	40.000	27.000	20.000	7.000	11309.730	848.230	0.718	1.675	350.000		BLADED
30	45.000	36.000	18.000	5.500	15268.137	1272.345	0.585	2.250	244.444		BLADED
31	38.000	30.000	23.000	6.500	13728.758	895.354	0.774	1.478	342.105	COMPACT	BLADED
32	53.000	36.000	18.000	7.000	17982.473	1498.540	0.554	2.472	264.151		BLADED
33	42.000	31.000	10.000	6.500	6817.254	1022.588	0.425	3.650	309.524	VERY	BLADED
34	77.000	30.000	18.000	7.000	21771.234	1814.270	0.520	2.972	181.818	VERY	ELONGATED
35	62.000	42.000	11.000	6.000	14997.961	2045.177	0.360	4.727	193.548	VERY	BLADED
36	45.000	35.000	31.000	8.000	25564.707	1237.002	0.848	1.290	355.555	COMPACT	ELONGATED
37	44.000	30.000	25.000	6.000	17278.758	1036.725	0.779	1.480	272.727	COMPACT	ELONGATED
38	50.000	35.000	30.000	9.500	27488.934	1374.447	0.801	1.417	380.000	COMPACT	ELONGATED
39	45.000	35.000	30.000	5.000	24740.039	1237.002	0.830	1.333	222.222	COMPACT	ELONGATED
40	51.000	30.000	23.000	8.000	18425.438	1201.659	0.702	1.761	313.725		ELONGATED
41	45.000	40.000	21.000	5.000	19792.031	1413.717	0.626	2.024	222.222		PLATY
42	60.000	50.000	21.000	5.000	32986.723	2356.194	0.528	2.619	166.667		PLATY
43	47.000	30.000	13.000	9.000	9597.563	1107.411	0.493	2.962	382.979	VERY	BLADED
44	32.000	24.000	14.000	5.000	5629.730	603.186	0.634	2.000	312.500		BLADED
45	51.000	24.000	23.000	5.000	14740.352	961.327	0.756	1.630	196.078		ELONGATED
46	47.000	46.000	12.000	9.000	13584.246	1698.031	0.405	3.875	382.979	VERY	PLATY
47	62.000	30.000	31.000	9.500	30190.703	1460.841	0.802	1.484	306.451		ELONGATED
48	53.000	47.000	18.000	9.500	23477.121	1956.427	0.507	2.778	358.490		PLATY
49	59.000	45.000	21.000	4.000	29193.246	2085.232	0.550	2.476	135.593		BLADED
50	40.000	31.000	28.000	4.000	18179.348	973.894	0.858	1.268	200.000	COMPACT	
51	53.000	32.000	14.000	9.000	12432.328	1332.035	0.487	3.036	339.623	VERY	BLADED
52	47.000	32.000	14.000	7.000	11024.895	1181.239	0.507	2.821	297.872	VERY	BLADED
53	50.000	44.000	29.000	8.000	33405.602	1727.876	0.726	1.621	320.000	COMPACT	PLATY
54	55.000	34.000	23.000	5.000	22519.980	1468.694	0.656	1.935	181.818		BLADED
55	35.000	29.000	17.000	6.500	9034.695	797.179	0.658	1.882	371.428		BLADED
56	36.000	29.000	17.000	3.500	9292.828	819.956	0.652	1.912	194.444		BLADED
57	33.000	29.000	20.000	4.000	10021.680	751.626	0.748	1.550	242.424	COMPACT	PLATY
58	73.000	34.000	16.000	6.000	20793.152	1949.358	0.469	3.344	164.384	VERY	ELONGATED
59	85.000	63.000	53.000	9.000	148605.125	4205.805	0.806	1.396	211.765	COMPACT	ELONGATED
60	80.000	40.000	33.000	7.000	55292.027	2513.274	0.698	1.818	175.000		ELONGATED
61	32.000	25.000	11.000	5.000	4607.668	628.318	0.533	2.591	312.500		BLADED
62	61.000	56.000	45.000	5.500	80487.563	2682.920	0.840	1.300	180.328	COMPACT	
63	85.000	72.000	61.000	9.500	195469.875	4806.637	0.847	1.287	223.529	COMPACT	
64	47.000	23.000	20.000	4.500	11320.203	849.015	0.718	1.750	191.489		ELONGATED
65	60.000	36.000	23.000	6.000	26012.387	1696.460	0.626	2.087	200.000		BLADED
66	76.000	32.000	20.000	5.000	25467.844	1910.088	0.548	2.700	131.579	VERY	ELONGATED
67	49.000	25.000	22.000	6.000	14110.984	962.113	0.734	1.682	244.898		ELONGATED
68	56.000	45.000	19.000	5.500	25069.906	1979.203	0.523	2.658	196.429		PLATY
69	45.000	26.000	14.000	5.000	8576.547	918.916	0.551	2.536	222.222	VERY	BLADED
70	44.000	24.000	18.000	5.000	9952.563	829.380	0.674	1.889	227.273		ELONGATED
71	65.000	53.000	20.000	5.000	36075.953	2705.697	0.488	2.950	153.846	VERY	PLATY
72	44.000	31.000	20.000	5.500	14283.773	1071.283	0.664	1.875	250.000		BLADED
73	82.000	57.000	31.000	9.500	75866.313	3670.951	0.590	2.242	231.707		BLADED
74	43.000	34.000	27.000	4.500	20668.535	1148.252	0.793	1.426	209.302	COMPACT	BLADED
75	46.000	17.000	17.000	4.500	6960.719	614.181	0.718	1.853	195.652		ELONGATED
76	55.000	37.000	17.000	5.000	18113.898	1598.285	0.522	2.706	181.818	VERY	BLADED
77	42.000	31.000	24.000	6.000	16361.414	1022.588	0.762	1.521	285.714	COMPACT	BLADED
78	56.000	34.000	17.000	4.500	16947.844	1495.398	0.533	2.647	160.714	VERY	BLADED
79	60.000	50.000	28.000	6.000	43982.297	2356.194	0.639	1.964	200.000		PLATY
80	88.000	55.000	44.000	8.500	111505.563	3801.327	0.737	1.625	193.182		ELONGATED
81	67.000	42.000	31.000	6.500	45675.613	2210.110	0.699	1.758	194.030		ELONGATED
82	30.000	27.000	21.000	9.000	8906.414	636.172	0.817	1.357	600.000	COMPACT	
83	45.000	27.000	18.000	3.500	11451.102	954.259	0.644	2.000	155.556		ELONGATED
84	36.000	27.000	13.000	4.500	6616.191	763.407	0.558	2.423	250.000		BLADED
85	67.000	33.000	21.000	6.000	24311.211	1736.515	0.584	2.381	179.104	VERY	ELONGATED
86	50.000	37.000	13.000	3.500	12592.547	1452.987	0.450	3.346	140.000	VERY	BLADED
87	68.000	36.000	17.000	7.000	21790.086	1922.655	0.491	3.059	205.882	VERY	BLADED
88	42.000	32.000	15.000	5.500	10555.750	1055.575	0.551	2.467	261.905		BLADED
89	93.000	40.000	24.000	5.000	46746.898	2921.681	0.537	2.771	107.527	VERY	ELONGATED
90	74.000	43.000	19.000	4.500	31655.734	2499.137	0.484	3.079	121.622	VERY	BLADED
91	40.000	33.000	20.000	8.000	13823.004	1036.725	0.672	1.825	400.000		BLADED
92	44.000	29.000	21.000	3.500	14030.352	1002.168	0.702	1.738	159.091		BLADED
93	66.000	31.000	16.000	5.000	17140.527	1606.925	0.500	3.031	151.515	VERY	ELONGATED
94	77.000	56.000	18.000	9.500	40639.641	3386.637	0.422	3.694	246.753	VERY	BLADED
95	41.000	25.000	10.000	5.500	5366.887	805.033	0.460	3.300	268.292	VERY	BLADED
96	46.000	23.000	19.000	5.000	10525.379	830.951	0.699	1.816	217.391		ELONGATED
97	40.000	19.000	15.000	3.000	5969.023	596.903	0.666	1.967	150.000		ELONGATED
98	72.000	53.000	46.000	8.500	91910.375	2997.079	0.822	1.359	236.111	COMPACT	ELONGATED
99	71.000	62.000	57.000	9.000	131378.250	3457.323	0.904	1.167	253.521	COMPACT	
100	44.000	35.000	17.000	3.500	13707.813	1209.513	0.573	2.324	159.091		BLADED

Table 99 Shape measurements of pebbles

FAN TWO SITE TWO

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	40.000	30.000	11.000	3.500	6911.500	942.478	0.465	3.182	175.000	VERY	BLADED
2	38.000	19.000	16.000	3.000	6048.609	567.057	0.708	1.781	157.895		ELONGATED
3	42.000	34.000	16.000	3.000	11963.184	1121.548	0.564	2.375	142.857		PLATY
4	50.000	25.000	10.000	4.000	6544.984	981.748	0.431	3.750	160.000	VERY	BLADED
5	36.000	31.000	10.000	6.000	5843.359	876.504	0.447	3.350	333.333	VERY	PLATY
6	37.000	27.000	14.000	3.000	7323.051	784.613	0.581	2.286	162.162		BLADED
7	39.000	31.000	13.000	4.000	8229.398	949.546	0.519	2.692	205.128	VERY	PLATY
8	39.000	21.000	12.000	5.000	5145.926	643.241	0.560	2.500	256.410	VERY	ELONGATED
9	41.000	20.000	17.000	4.500	7298.965	644.026	0.706	1.794	219.512		ELONGATED
10	44.000	24.000	19.000	5.000	10505.484	829.380	0.699	1.789	227.273		ELONGATED
11	42.000	32.000	20.000	5.000	14074.332	1055.575	0.668	1.850	238.095		BLADED
12	32.000	22.000	21.000	6.000	7740.883	552.920	0.856	1.286	375.000	COMPACT	ELONGATED
13	46.000	33.000	14.000	3.500	11127.520	1192.234	0.505	2.821	152.174	VERY	BLADED
14	46.000	22.000	15.000	3.000	7948.227	794.823	0.606	2.267	130.435	VERY	ELONGATED
15	42.000	32.000	28.000	4.000	19704.066	1055.575	0.836	1.321	190.476	COMPACT	ELONGATED
16	40.000	23.000	15.000	5.500	7225.660	722.566	0.625	2.100	275.000		ELONGATED
17	47.000	28.000	14.000	4.500	9646.781	1033.584	0.530	2.679	191.489	VERY	BLADED
18	40.000	36.000	19.000	6.500	14325.660	1130.973	0.631	2.000	325.000		PLATY
19	50.000	30.000	20.000	5.000	15707.961	1178.097	0.644	2.000	200.000		ELONGATED
20	36.000	26.000	19.000	3.500	9311.680	735.133	0.728	1.632	194.444	COMPACT	BLADED
21	53.000	27.000	14.000	5.000	10489.777	1123.905	0.515	2.857	188.679	VERY	ELONGATED
22	29.000	19.000	12.000	5.000	3462.035	432.754	0.639	2.000	344.827		BLADED
23	37.000	19.000	16.000	4.000	5889.438	552.135	0.714	1.750	216.216		ELONGATED
24	36.000	25.000	13.000	5.000	6126.105	706.858	0.573	2.346	277.778		BLADED
25	36.000	22.000	17.000	3.000	7049.730	622.035	0.715	1.706	166.667		ELONGATED
26	35.000	32.000	12.000	3.500	7037.164	879.646	0.505	2.792	200.000		PLATY
27	52.000	47.000	12.000	9.000	15356.102	1919.513	0.389	4.125	346.154	VERY	PLATY
28	42.000	31.000	12.000	5.000	8180.707	1022.588	0.480	3.042	238.095	VERY	BLADED
29	53.000	41.000	28.000	5.000	31857.844	1706.670	0.712	1.679	188.679	COMPACT	BLADED
30	37.000	25.000	14.000	5.000	6780.602	726.493	0.596	2.214	270.270		BLADED
31	39.000	27.000	18.000	4.500	9924.289	827.024	0.675	1.833	230.769		BLADED
32	37.000	17.000	17.000	5.500	5598.840	494.015	0.772	1.588	297.297		ELONGATED
33	30.000	30.000	18.000	6.000	8482.297	706.858	0.711	1.667	400.000	COMPACT	PLATY
34	52.000	39.000	14.000	7.000	14866.016	1592.787	0.459	3.250	269.231	VERY	BLADED
35	45.000	25.000	12.000	4.500	7068.582	883.573	0.504	2.917	200.000	VERY	BLADED
36	49.000	35.000	17.000	4.500	15265.520	1346.958	0.552	2.471	183.673		BLADED
37	38.000	25.000	18.000	6.000	8953.539	746.128	0.699	1.750	315.789		BLADED
38	47.000	33.000	18.000	6.000	14617.828	1218.152	0.593	2.222	255.319		BLADED
39	36.000	22.000	16.000	6.000	6635.043	622.035	0.686	1.813	333.333		ELONGATED
40	35.000	25.000	15.000	5.000	6872.230	687.223	0.636	2.000	285.714		BLADED
41	42.000	26.000	23.000	6.000	13150.703	857.655	0.785	1.478	285.714	COMPACT	ELONGATED
42	35.000	22.000	23.000	4.000	9272.934	604.756	0.882	1.239	228.571	COMPACT	ELONGATED
43	36.000	22.000	19.000	5.000	7879.113	622.035	0.770	1.526	277.778	COMPACT	ELONGATED
44	31.000	21.000	11.000	4.500	3749.491	511.294	0.571	2.364	290.323		BLADED
45	31.000	23.000	21.000	6.000	7839.844	559.989	0.852	1.286	387.097	COMPACT	ELONGATED
46	45.000	30.000	13.000	5.000	9189.156	1060.287	0.500	2.885	222.222	VERY	BLADED
47	45.000	36.000	11.000	3.000	9330.527	1272.345	0.421	3.682	133.333	VERY	PLATY
48	36.000	34.000	25.000	5.000	16022.121	961.327	0.799	1.400	277.778	COMPACT	PLATY
49	48.000	34.000	15.000	8.000	12817.695	1281.770	0.517	2.733	333.333	VERY	BLADED
50	49.000	35.000	15.000	5.000	13469.578	1346.958	0.508	2.800	204.082	VERY	BLADED
51	35.000	21.000	13.000	2.500	5002.984	577.268	0.613	2.154	142.857		BLADED
52	31.000	25.000	18.000	7.000	7304.199	608.683	0.748	1.556	451.613	COMPACT	BLADED
53	57.000	29.000	18.000	7.000	15579.156	1298.263	0.581	2.389	245.614	VERY	ELONGATED
54	58.000	26.000	16.000	5.000	12633.391	1184.380	0.554	2.625	172.414	VERY	ELONGATED
55	36.000	31.000	18.000	5.500	10518.051	876.504	0.662	1.861	305.555		PLATY
56	31.000	29.000	23.000	5.000	10826.449	706.073	0.838	1.304	322.581	COMPACT	
57	50.000	43.000	18.000	6.000	20263.270	1688.606	0.532	2.583	240.000		PLATY
58	41.000	30.000	10.000	4.500	6440.262	966.040	0.433	3.550	219.512	VERY	BLADED
59	42.000	28.000	11.000	3.500	6773.273	923.628	0.469	3.182	166.667	VERY	BLADED
60	40.000	33.000	13.000	3.500	8984.953	1036.725	0.504	2.808	175.000	VERY	PLATY
61	36.000	16.000	15.000	4.000	4523.891	452.389	0.731	1.733	222.222		ELONGATED
62	40.000	22.000	16.000	3.500	7372.270	691.150	0.663	1.938	175.000		ELONGATED
63	40.000	34.000	19.000	4.500	13529.789	1068.141	0.643	1.947	225.000		PLATY
64	34.000	30.000	15.000	6.500	8011.059	801.106	0.604	2.133	382.353		PLATY
65	36.000	25.000	18.000	4.500	8482.297	706.858	0.711	1.694	250.000		BLADED
66	30.000	23.000	17.000	5.000	6141.813	541.925	0.748	1.559	333.333	COMPACT	BLADED
67	35.000	24.000	19.000	4.000	8356.633	659.734	0.755	1.553	228.571	COMPACT	ELONGATED
68	35.000	20.000	15.000	4.000	5497.785	549.779	0.685	1.833	228.571		ELONGATED
69	25.000	18.000	14.000	3.500	3298.672	353.429	0.758	1.536	280.000	COMPACT	BLADED
70	31.000	22.000	18.000	3.000	6427.695	535.641	0.780	1.472	193.548	COMPACT	ELONGATED
71	44.000	36.000	13.000	3.500	10781.945	1244.071	0.474	3.077	159.091	VERY	PLATY
72	45.000	40.000	19.000	5.500	17907.078	1413.717	0.585	2.237	244.444		PLATY
73	40.000	22.000	18.000	5.000	8293.801	691.150	0.717	1.722	250.000		ELONGATED
74	40.000	25.000	17.000	5.000	8901.176	785.398	0.661	1.912	250.000		BLADED
75	37.000	24.000	18.000	5.500	8369.199	697.433	0.715	1.694	297.297		ELONGATED
76	29.000	25.000	17.000	4.500	6453.352	569.414	0.736	1.588	310.345	COMPACT	BLADED
77	32.000	20.000	15.000	4.500	5026.547	502.655	0.706	1.733	281.250		ELONGATED
78	37.000	20.000	11.000	4.500	4262.094	581.195	0.547	2.591	243.243	VERY	BLADED
79	38.000	21.000	18.000	3.500	7520.973	626.748	0.740	1.639	184.211		ELONGATED
80	47.000	30.000	14.000	7.000	10335.836	1107.411	0.518	2.750	297.872	VERY	BLADED
81	38.000	28.000	16.000	4.000	8913.742	835.664	0.622	2.063	210.526		BLADED
82	31.000	20.000	17.000	3.000	5518.730	486.947	0.775	1.500	193.548	COMPACT	ELONGATED
83	29.000	24.000	14.000	3.000	5101.945	546.637	0.655	1.893	206.897		BLADED
84	35.000	27.000	11.000	3.000	5442.809	742.201	0.504	2.818	171.429	VERY	BLADED
85	41.000	24.000	15.000	5.000	7728.316	772.832	0.611	2.167	243.902		BLADED
86	34.000	27.000	20.000	5.000	9613.273	720.995	0.758	1.525	294.117	COMPACT	BLADED
87	40.000	19.000	15.000	5.500	5969.023	596.903	0.666	1.967	275.000		ELONGATED
88	31.000	21.000	19.000	3.500	6476.391	511.294	0.822	1.368	225.806	COMPACT	ELONGATED
89	27.000	17.000	15.000	4.500	3604.978	360.498	0.788	1.467	333.333	COMPACT	ELONGATED
90	29.000	18.000	15.000	5.000	4099.777	409.978	0.755	1.567	344.827	COMPACT	ELONGATED
91	36.000	24.000	18.000	5.500	8143.008	678.584	0.721	1.667	305.555		ELONGATED
92	30.000	20.000	20.000	5.000	6283.184	471.239	0.874	1.250	333.333	COMPACT	ELONGATED
93	27.000	26.000	11.000	5.500	4043.230	551.349	0.557	2.409	407.407		PLATY
94	40.000	22.000	11.000	3.500	5068.434	691.150	0.516	2.818	175.000	VERY	BLADED
95	30.000	20.000	20.000	5.000	6283.184	471.239	0.874	1.250	333.333	COMPACT	ELONGATED
96	31.000	21.000	13.000	5.000	4431.215	511.294	0.638	2.000	322.581		BLADED
97	34.000	25.000	17.000	3.500	7566.000	667.588	0.698	1.735	205.882		BLADED
98	37.000	23.000	16.000	4.500	7129.320	668.374	0.670	1.875	243.243		ELONGATED
99	31.000	20.000	19.000	4.500	6167.992	486.947	0.835	1.342	290.323	COMPACT	ELONGATED
100	44.000	18.000	11.000	3.000	4561.590	622.035	0.535	2.818	136.364	VERY	ELONGATED

Table 100 Shape measurements of pebbles

FAN TWO SITE THREE

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	80.000	56.000	23.000	7.000	53951.617	3518.584	0.491	2.957	175.000	VERY	BLADED
2	90.000	63.000	38.000	9.500	112814.563	4453.207	0.634	2.013	211.111		BLADED
3	75.000	55.000	21.000	8.500	45356.742	3239.767	0.475	3.095	226.667	VERY	BLADED
4	80.000	30.000	22.000	6.000	27646.012	1884.956	0.586	2.500	150.000	VERY	ELONGATED
5	75.000	53.000	37.000	8.000	77008.250	3121.958	0.701	1.730	213.333		BLADED
6	90.050	6.020	1.050	0.500	298.035	425.765	0.127	45.748	11.105	VERY	ELONGATED
7	85.000	50.000	23.000	7.000	51181.777	3337.942	0.499	2.935	164.706	VERY	BLADED
8	95.000	75.000	40.000	8.500	149225.625	5595.961	0.608	2.125	178.947		BLADED
9	85.000	40.000	15.000	8.000	26703.535	2670.354	0.404	4.167	188.235	VERY	BLADED
10	90.000	40.000	22.000	8.000	41469.020	2827.433	0.512	2.955	177.778	VERY	ELONGATED
11	78.000	41.000	19.000	6.000	31814.906	2511.703	0.483	3.132	153.846	VERY	BLADED
12	70.000	40.000	26.000	5.000	38117.988	2199.115	0.623	2.115	142.857		ELONGATED
13	70.000	45.000	13.000	5.000	21441.367	2474.004	0.377	4.423	142.857	VERY	BLADED
14	96.000	35.000	20.000	8.500	35185.836	2638.938	0.492	3.275	177.083	VERY	ELONGATED
15	75.000	40.000	18.000	2.500	28274.332	2356.194	0.476	3.194	66.667	VERY	BLADED
16	65.000	45.000	20.000	8.000	30630.527	2297.290	0.515	2.750	246.154	VERY	BLADED
17	75.000	30.000	19.000	4.000	22383.848	1767.146	0.543	2.763	106.667	VERY	ELONGATED
18	80.000	45.000	28.000	7.000	52778.754	2827.433	0.602	2.232	175.000		ELONGATED
19	75.000	45.000	24.000	6.000	42411.500	2650.719	0.555	2.500	160.000	VERY	BLADED
20	95.000	65.000	20.000	8.000	64664.445	4849.832	0.402	4.000	168.421	VERY	BLADED
21	66.000	40.000	26.000	9.000	35939.816	2073.451	0.635	2.038	272.727		BLADED
22	65.000	45.000	19.000	6.000	29099.000	2297.290	0.498	2.895	184.615	VERY	BLADED
23	70.000	45.000	32.000	7.000	52778.754	2474.004	0.688	1.797	200.000		BLADED
24	56.000	55.000	42.000	8.000	67732.688	2419.026	0.830	1.321	285.714	COMPACT	
25	78.000	47.000	23.000	9.000	44148.801	2879.270	0.525	2.717	230.769	VERY	BLADED
26	60.000	40.000	21.000	8.000	26389.375	1884.956	0.569	2.381	266.667		BLADED
27	70.000	45.000	18.000	4.500	29688.047	2474.004	0.469	3.194	128.571	VERY	BLADED
28	90.000	40.000	37.000	5.000	69743.313	2827.433	0.724	1.757	111.111		ELONGATED
29	70.000	50.000	30.000	9.000	54977.871	2748.894	0.636	2.000	257.143		BLADED
30	85.000	60.000	25.000	7.500	66758.813	4005.531	0.497	2.900	176.471	VERY	BLADED
31	75.000	40.000	35.000	6.000	54977.871	2356.194	0.742	1.643	160.000		ELONGATED
32	70.000	50.000	25.000	9.000	45814.891	2748.894	0.563	2.400	257.143		BLADED
33	75.000	50.000	25.000	9.000	49087.383	2945.243	0.550	2.500	240.000	VERY	BLADED
34	65.000	55.000	37.000	5.000	69259.000	2807.798	0.726	1.622	153.846	COMPACT	BLADED
35	70.000	40.000	30.000	7.000	43982.297	2199.115	0.685	1.833	200.000		ELONGATED
36	80.000	70.000	27.000	9.500	79168.125	4398.227	0.507	2.778	237.500		PLATY
37	90.000	45.000	22.000	8.500	46652.648	3180.863	0.493	3.068	188.889	VERY	BLADED
38	70.000	50.000	18.000	9.000	32986.723	2748.894	0.452	3.333	257.143	VERY	BLADED
39	60.000	60.000	25.000	9.500	47123.887	2827.433	0.558	2.400	316.667		PLATY
40	70.000	40.000	33.000	8.500	48380.523	2199.115	0.730	1.667	242.857		ELONGATED
41	80.000	45.000	27.000	5.000	50893.801	2827.433	0.587	2.315	125.000		BLADED
42	72.000	50.000	23.000	9.500	43353.977	2827.433	0.528	2.652	263.889	VERY	BLADED
43	70.000	32.000	25.000	6.000	29321.531	1759.292	0.653	2.040	171.429		ELONGATED
44	80.000	75.000	70.000	9.500	219911.438	4712.387	0.935	1.107	237.500	COMPACT	
45	70.000	40.000	39.000	6.500	57176.984	2199.115	0.816	1.410	185.714	COMPACT	ELONGATED
46	55.000	52.000	19.000	9.500	28452.355	2246.239	0.502	2.816	345.454		PLATY
47	63.000	60.000	32.000	9.000	63334.508	2968.805	0.647	1.922	285.714	COMPACT	PLATY
48	70.000	35.000	19.000	5.000	24373.520	1924.225	0.528	2.763	142.857	VERY	ELONGATED
49	70.000	40.000	33.000	6.500	48380.523	2199.115	0.730	1.667	185.714		ELONGATED
50	50.000	30.000	23.000	5.000	18064.156	1178.097	0.707	1.739	200.000		ELONGATED
51	45.000	40.000	35.000	9.000	32986.723	1413.717	0.880	1.214	400.000	COMPACT	
52	35.000	30.000	28.000	9.500	15393.801	824.668	0.907	1.161	542.857	COMPACT	
53	40.000	35.000	30.000	8.500	21991.148	1099.557	0.863	1.250	425.000	COMPACT	
54	30.000	25.000	20.000	3.500	7853.980	589.049	0.811	1.375	233.333	COMPACT	BLADED
55	40.000	20.000	15.000	3.000	6283.184	628.318	0.655	2.000	150.000		ELONGATED
56	24.000	20.000	18.000	6.500	4523.891	376.991	0.877	1.222	541.667	COMPACT	
57	40.000	35.000	27.000	7.000	19792.031	1099.557	0.805	1.389	350.000	COMPACT	BLADED
58	30.000	29.000	22.000	6.500	10021.680	683.296	0.822	1.341	433.333	COMPACT	
59	38.000	36.000	32.000	8.000	22921.059	1074.425	0.908	1.156	421.052	COMPACT	
60	31.000	30.000	25.000	5.000	12173.668	730.420	0.876	1.220	322.581	COMPACT	
61	31.000	30.000	28.000	4.500	13634.512	730.420	0.945	1.089	290.323	COMPACT	
62	34.000	30.000	26.000	7.000	13885.836	801.106	0.872	1.231	411.765	COMPACT	
63	32.000	28.000	22.000	6.000	10321.176	703.717	0.814	1.364	375.000	COMPACT	BLADED
64	28.000	23.000	12.000	5.000	4046.371	505.796	0.607	2.125	357.143		PLATY
65	50.000	30.000	20.000	4.500	15707.961	1178.097	0.644	2.000	180.000		ELONGATED
66	31.000	30.000	29.000	6.500	14121.457	730.420	0.967	1.052	419.355	COMPACT	
67	30.000	25.000	20.000	2.500	7853.980	589.049	0.811	1.375	166.667	COMPACT	BLADED
68	27.000	24.000	23.000	9.000	7803.715	508.938	0.935	1.109	666.667	COMPACT	
69	32.000	28.000	24.000	2.500	11259.465	703.717	0.863	1.250	156.250	COMPACT	
70	30.000	25.000	20.000	7.000	7853.980	589.049	0.811	1.375	466.667	COMPACT	BLADED
71	32.000	27.000	25.000	7.000	11309.730	678.584	0.898	1.180	437.500	COMPACT	
72	30.000	25.000	20.000	4.000	7853.980	589.049	0.811	1.375	266.667	COMPACT	BLADED
73	44.000	40.000	20.000	2.500	18430.676	1382.301	0.610	2.100	113.636		PLATY
74	35.000	33.000	27.000	7.000	16328.426	907.135	0.858	1.259	400.000	COMPACT	
75	30.000	29.000	24.000	6.500	10932.742	683.296	0.872	1.229	433.333	COMPACT	
76	35.000	27.000	25.000	3.500	12370.020	742.201	0.871	1.240	200.000	COMPACT	
77	32.000	27.000	23.000	3.000	10404.953	678.584	0.849	1.283	187.500	COMPACT	
78	28.000	25.000	20.000	7.500	7330.383	549.779	0.830	1.325	535.714	COMPACT	
79	40.000	36.000	27.000	8.000	20357.520	1130.973	0.797	1.407	400.000	COMPACT	PLATY
80	36.000	33.000	30.000	3.500	18661.059	933.053	0.912	1.150	194.444	COMPACT	
81	45.000	40.000	25.000	4.500	23561.941	1413.717	0.703	1.700	200.000	COMPACT	PLATY
82	40.000	38.000	24.000	7.000	19100.883	1193.805	0.724	1.625	350.000	COMPACT	PLATY
83	43.000	37.000	34.000	9.500	28323.551	1249.568	0.899	1.176	441.860	COMPACT	
84	28.000	25.000	24.000	4.500	8796.457	549.779	0.937	1.104	321.428	COMPACT	
85	34.000	30.000	20.000	2.500	10681.414	801.106	0.732	1.600	147.059	COMPACT	PLATY
86	40.000	35.000	34.000	7.000	24923.301	1099.557	0.938	1.103	350.000	COMPACT	
87	35.000	30.000	25.000	6.500	13744.465	824.668	0.841	1.300	371.428	COMPACT	
88	37.000	35.000	30.000	9.000	20341.809	1017.091	0.886	1.200	486.486	COMPACT	
89	34.000	30.000	27.000	7.500	14419.910	801.106	0.894	1.185	441.176	COMPACT	
90	38.000	30.000	16.000	6.000	9550.441	895.354	0.608	2.125	315.789		BLADED
91	45.000	36.000	30.000	9.500	25446.898	1272.345	0.822	1.350	422.222	COMPACT	BLADED
92	32.000	30.000	20.000	3.500	10053.094	753.982	0.747	1.550	218.750	COMPACT	PLATY
93	31.000	28.000	27.000	2.000	12271.059	681.726	0.943	1.093	129.032	COMPACT	
94	25.000	23.000	16.000	4.000	4817.105	451.604	0.764	1.500	320.000	COMPACT	PLATY
95	32.000	26.000	24.000	6.500	10455.219	653.451	0.885	1.208	406.250	COMPACT	
96	34.000	20.000	15.000	5.500	5340.707	534.071	0.692	1.800	323.529		ELONGATED
97	25.000	23.000	15.000	5.000	4516.039	451.604	0.731	1.600	400.000	COMPACT	PLATY
98	30.000	26.000	20.000	4.500	8168.141	612.610	0.800	1.400	300.000	COMPACT	BLADED
99	25.000	21.000	15.000	3.500	4123.340	412.334	0.754	1.533	280.000	COMPACT	BLADED
100	45.000	34.000	30.000	9.500	24033.184	1201.659	0.838	1.317	422.222	COMPACT	ELONGATED

Table 101 Shape measurements of pebbles

(II-152)

FAN TWO SITE FOUR

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	25.000	15.000	13.000	5.500	2552.544	294.524	0.767	1.538	440.000	COMPACT	ELONGATED
2	25.000	24.000	20.000	4.500	6283.184	471.239	0.874	1.225	360.000	COMPACT	
3	30.000	23.000	16.000	2.000	5780.527	541.925	0.719	1.656	133.333	COMPACT	BLADED
4	25.000	24.000	23.000	4.500	7225.660	471.239	0.959	1.065	360.000	COMPACT	
5	29.000	25.000	23.000	3.500	8731.008	569.414	0.900	1.174	241.379	COMPACT	
6	24.000	23.000	10.000	2.000	2890.265	433.540	0.566	2.350	166.667		PLATY
7	28.000	23.000	12.000	6.500	4046.371	505.796	0.607	2.125	464.286		PLATY
8	26.000	23.000	14.000	2.000	4383.566	469.668	0.689	1.750	153.846	COMPACT	PLATY
9	27.000	25.000	17.000	4.500	6008.293	530.144	0.754	1.529	333.333	COMPACT	PLATY
10	22.000	20.000	19.000	5.000	4377.285	345.575	0.936	1.105	454.545	COMPACT	
11	38.000	35.000	30.000	4.500	20891.590	1044.579	0.878	1.217	236.842	COMPACT	
12	39.000	38.000	26.000	3.000	20175.305	1163.960	0.770	1.481	153.846	COMPACT	PLATY
13	32.000	26.000	22.000	5.000	9583.949	653.451	0.835	1.318	312.500	COMPACT	BLADED
14	27.000	23.000	15.000	6.500	4877.320	487.732	0.713	1.667	481.481	COMPACT	BLADED
15	31.000	25.000	20.000	8.000	8115.777	608.683	0.802	1.400	516.129	COMPACT	BLADED
16	26.000	20.000	19.000	9.500	5173.152	408.407	0.885	1.211	730.769	COMPACT	
17	26.000	25.000	20.000	3.500	6806.781	510.509	0.851	1.275	269.231	COMPACT	
18	39.000	36.000	33.000	7.500	24259.375	1102.699	0.919	1.136	384.615	COMPACT	
19	27.000	26.000	25.000	6.500	9189.156	551.349	0.962	1.060	481.481	COMPACT	
20	40.000	24.000	20.000	3.500	10053.094	753.982	0.747	1.600	175.000		ELONGATED
21	30.000	26.000	21.000	5.000	8576.547	612.610	0.827	1.333	333.333	COMPACT	
22	35.000	23.000	20.000	4.500	8429.938	632.245	0.792	1.450	257.143	COMPACT	ELONGATED
23	39.000	36.000	27.000	6.000	19848.582	1102.699	0.804	1.389	307.692	COMPACT	PLATY
24	40.000	38.000	31.000	7.000	24671.973	1193.805	0.858	1.258	350.000	COMPACT	
25	50.000	36.000	35.000	7.500	32986.723	1413.717	0.880	1.229	300.000	COMPACT	
26	26.000	20.000	18.000	3.500	4900.883	408.407	0.854	1.278	269.231	COMPACT	ELONGATED
27	29.000	27.000	21.000	4.000	8609.531	614.967	0.826	1.333	275.862	COMPACT	
28	30.000	26.000	25.000	4.500	10210.176	612.610	0.929	1.120	300.000	COMPACT	
29	35.000	30.000	20.000	6.500	10995.574	824.668	0.725	1.625	371.428	COMPACT	BLADED
30	29.000	20.000	19.000	6.000	5770.055	455.531	0.854	1.289	413.793	COMPACT	ELONGATED
31	37.000	35.000	28.000	4.500	18985.691	1017.091	0.846	1.286	243.243	COMPACT	
32	25.000	22.000	18.000	3.000	5183.625	431.969	0.838	1.306	240.000	COMPACT	
33	39.000	30.000	20.000	5.000	12252.211	918.916	0.699	1.725	256.410	COMPACT	BLADED
34	38.000	35.000	26.000	5.000	18106.043	1044.579	0.798	1.404	263.158	COMPACT	PLATY
35	36.000	30.000	28.000	4.500	15833.625	848.230	0.899	1.179	250.000	COMPACT	
36	34.000	28.000	25.000	3.500	12461.648	747.699	0.869	1.240	205.882	COMPACT	
37	30.000	29.000	19.000	4.000	8655.086	683.296	0.746	1.553	266.667	COMPACT	PLATY
38	38.000	33.000	26.000	6.000	17071.414	984.889	0.814	1.365	315.789	COMPACT	BLADED
39	34.000	31.000	25.000	5.000	13796.824	827.810	0.840	1.300	294.117	COMPACT	
40	30.000	29.000	25.000	4.500	11388.270	683.296	0.896	1.180	300.000	COMPACT	
41	31.000	28.000	27.000	5.000	12271.059	681.726	0.943	1.093	322.581	COMPACT	
42	30.000	22.000	20.000	4.500	6911.500	518.363	0.846	1.300	300.000	COMPACT	ELONGATED
43	30.000	28.000	25.000	7.000	10995.574	659.734	0.906	1.160	466.667	COMPACT	
44	30.000	25.000	24.000	6.500	9424.777	589.049	0.916	1.146	433.333	COMPACT	
45	21.000	26.000	23.000	5.000	6575.352	428.827	0.990	1.022	476.190	COMPACT	
46	34.000	25.000	15.000	3.000	6675.883	667.588	0.642	1.967	176.471		BLADED
47	35.000	25.000	15.000	3.500	6872.230	687.223	0.636	2.000	200.000		BLADED
48	35.000	29.000	27.000	4.500	14349.223	797.179	0.896	1.185	257.143	COMPACT	
49	32.000	28.000	27.000	8.000	12666.898	703.717	0.934	1.111	500.000	COMPACT	
50	37.000	23.000	20.000	6.500	8911.648	668.374	0.778	1.500	351.351	COMPACT	ELONGATED
51	30.000	25.000	23.000	8.500	9032.078	589.049	0.890	1.196	566.667	COMPACT	
52	35.000	31.000	27.000	4.000	15338.824	852.157	0.876	1.222	228.571	COMPACT	
53	36.000	34.000	23.000	3.000	14740.352	961.327	0.756	1.522	166.667	COMPACT	PLATY
54	37.000	35.000	17.000	8.500	11527.023	1017.091	0.607	2.118	459.459		PLATY
55	39.000	37.000	30.000	9.500	22666.590	1133.329	0.854	1.267	487.179	COMPACT	
56	25.000	22.000	19.000	8.000	5471.605	431.969	0.869	1.237	640.000	COMPACT	
57	42.000	32.000	25.000	6.500	17592.918	1055.575	0.775	1.480	309.524	COMPACT	BLADED
58	51.000	47.000	17.000	7.000	21336.125	1882.599	0.494	2.882	274.510	VERY	PLATY
59	40.000	36.000	27.000	4.500	20357.520	1130.973	0.797	1.407	225.000	COMPACT	PLATY
60	26.000	21.000	20.000	8.500	5717.695	428.827	0.901	1.175	653.846	COMPACT	
61	31.000	30.000	29.000	9.500	14121.457	730.420	0.967	1.052	612.903	COMPACT	
62	27.000	26.000	25.000	7.000	9189.156	551.349	0.962	1.060	518.518	COMPACT	
63	35.000	34.000	30.000	6.500	18692.473	934.624	0.911	1.150	371.428	COMPACT	
64	25.000	24.000	22.000	9.000	6911.500	471.239	0.931	1.114	720.000	COMPACT	
65	34.000	33.000	30.000	2.500	17624.332	881.217	0.929	1.117	147.059	COMPACT	
66	29.000	23.000	21.000	4.500	7334.047	523.860	0.871	1.238	310.345	COMPACT	
67	29.000	24.000	16.000	6.500	5830.793	546.637	0.716	1.656	448.276	COMPACT	BLADED
68	25.000	23.000	20.000	5.000	6021.383	451.604	0.886	1.200	400.000	COMPACT	
69	35.000	30.000	11.000	7.500	6047.563	824.668	0.487	2.955	428.571	VERY	PLATY
70	30.000	25.000	20.000	5.000	7853.980	589.049	0.811	1.375	333.333	COMPACT	BLADED
71	26.000	25.000	21.000	8.500	7147.121	510.509	0.879	1.214	653.846	COMPACT	
72	31.000	21.000	20.000	5.500	6817.254	511.294	0.850	1.300	354.839	COMPACT	ELONGATED
73	22.000	21.000	20.000	6.500	4838.051	362.854	0.953	1.075	590.909	COMPACT	
74	30.000	25.000	23.000	6.500	9032.078	589.049	0.890	1.196	433.333	COMPACT	
75	20.000	19.000	15.000	4.000	2984.513	298.451	0.840	1.300	400.000	COMPACT	
76	30.000	29.000	17.000	6.000	7744.023	683.296	0.693	1.735	400.000	COMPACT	PLATY
77	31.000	30.000	18.000	6.500	8765.043	730.420	0.704	1.694	419.355	COMPACT	PLATY
78	27.000	25.000	15.000	3.500	5301.438	530.144	0.693	1.733	259.259	COMPACT	PLATY
79	35.000	29.000	26.000	5.000	13817.770	797.179	0.873	1.231	285.714	COMPACT	
80	36.000	30.000	25.000	4.000	14137.164	848.230	0.833	1.320	222.222	COMPACT	BLADED
81	28.000	27.000	25.000	7.500	9896.016	593.761	0.939	1.100	535.714	COMPACT	
82	35.000	34.000	26.000	6.500	16200.145	934.624	0.828	1.327	371.428	COMPACT	
83	26.000	25.000	21.000	6.500	7147.121	510.509	0.879	1.214	500.000	COMPACT	
84	26.000	23.000	16.000	4.000	5009.793	469.668	0.754	1.531	307.692	COMPACT	PLATY
85	35.000	29.000	24.000	4.500	12754.863	797.179	0.828	1.333	257.143	COMPACT	BLADED
86	31.000	27.000	25.000	6.000	10956.301	657.378	0.907	1.160	387.097	COMPACT	
87	30.000	29.000	20.000	8.500	9110.617	683.296	0.772	1.475	566.667	COMPACT	PLATY
88	26.000	23.000	13.000	5.500	4070.457	469.668	0.656	1.885	423.077		PLATY
89	36.000	36.000	10.000	2.500	6785.840	1017.876	0.426	3.600	138.889	VERY	PLATY
90	24.000	23.000	14.000	3.500	4046.371	433.540	0.708	1.679	291.667	COMPACT	PLATY
91	23.000	22.000	21.000	7.500	5563.758	397.411	0.955	1.071	652.174	COMPACT	
92	30.000	27.000	18.000	5.500	7634.066	636.172	0.737	1.583	366.667	COMPACT	PLATY
93	27.000	24.000	23.000	9.000	7803.715	508.938	0.935	1.109	666.667	COMPACT	
94	31.000	27.000	17.000	8.500	7450.285	657.378	0.702	1.706	548.387	COMPACT	PLATY
95	35.000	33.000	18.000	6.500	10885.617	907.135	0.655	1.889	371.428	COMPACT	PLATY
96	26.000	20.000	14.000	3.500	3811.799	408.407	0.722	1.643	269.231	COMPACT	BLADED
97	30.000	25.000	19.000	6.000	7461.281	589.049	0.784	1.447	400.000	COMPACT	BLADED
98	30.000	25.000	23.000	7.500	9032.078	589.049	0.890	1.196	500.000	COMPACT	
99	31.000	26.000	24.000	9.500	10128.492	633.031	0.894	1.188	612.903	COMPACT	
100	29.000	27.000	18.000	6.500	7379.598	614.967	0.745	1.556	448.276	COMPACT	PLATY

Table 102 Shape measurements of pebbles

FAN TWO SITE FIVE

(II-153)

PEBBLE	LENGTH	MEDIUM	SHORT	RAD OF CURV	VOLUME	AREA(MAX)	SPHERICITY	FLATNESS	ROUNDNESS	FORM	CLASS
1	30.000	24.000	15.000	3.500	5654.863	565.487	0.679	1.800	233.333		BLADED
2	25.000	22.000	20.000	6.500	5759.586	431.969	0.899	1.175	520.000	COMPACT	
3	30.000	26.000	20.000	5.000	8168.141	612.610	0.800	1.400	333.333	COMPACTBLADED	
4	23.000	21.000	18.000	4.000	4552.164	379.347	0.875	1.222	347.826	COMPACT	
5	29.000	23.000	21.000	7.000	7334.047	523.860	0.871	1.238	482.759	COMPACT	
6	32.000	27.000	25.000	5.500	11309.730	678.584	0.898	1.180	343.750	COMPACT	
7	29.000	26.000	25.000	6.000	9869.836	592.190	0.939	1.100	413.793	COMPACT	
8	30.000	28.000	22.000	7.000	9676.102	659.734	0.832	1.318	466.667	COMPACT	
9	29.000	27.000	25.000	9.000	10249.445	614.967	0.928	1.120	620.689	COMPACT	
10	29.000	28.000	27.000	6.500	11479.379	637.743	0.965	1.056	448.276	COMPACT	
11	23.000	22.000	21.000	5.500	5563.758	397.411	0.955	1.071	478.261	COMPACT	
12	30.000	29.000	28.000	9.000	12754.863	683.296	0.966	1.054	600.000	COMPACT	
13	23.000	22.000	21.000	8.500	5563.758	397.411	0.955	1.071	739.130	COMPACT	
14	35.000	30.000	20.000	4.500	10995.574	824.668	0.725	1.625	257.143	COMPACTBLADED	
15	37.000	31.000	29.000	6.500	17416.465	900.852	0.902	1.172	351.351	COMPACT	
16	32.000	26.000	25.000	9.500	10890.852	653.451	0.909	1.160	593.750	COMPACT	
17	36.000	34.000	26.000	7.500	16663.004	961.327	0.820	1.346	416.667	COMPACT	
18	34.000	26.000	23.000	7.000	10645.809	694.292	0.843	1.304	411.765	COMPACTELONGATED	
19	29.000	28.000	22.000	3.500	9353.566	637.743	0.842	1.295	241.379	COMPACT	
20	31.000	27.000	26.000	9.000	11394.555	657.378	0.931	1.115	580.645	COMPACT	
21	40.000	34.000	25.000	5.500	17802.355	1068.141	0.772	1.480	275.000	COMPACTBLADED	
22	34.000	31.000	28.000	8.500	15452.445	827.810	0.906	1.161	500.000	COMPACT	
23	32.000	26.000	22.000	6.000	9583.949	653.451	0.835	1.318	375.000	COMPACTBLADED	
24	33.000	31.000	21.000	5.000	11248.469	803.462	0.755	1.524	303.030	COMPACTPLATY	
25	24.000	20.000	17.000	7.500	4272.563	376.991	0.844	1.294	625.000	COMPACT	
26	32.000	27.000	19.000	9.500	8595.395	678.584	0.748	1.553	593.750	COMPACTBLADED	
27	40.000	33.000	21.000	5.500	14514.156	1036.725	0.694	1.738	275.000	COMPACTBLADED	
28	35.000	31.000	21.000	8.500	11930.195	852.157	0.741	1.571	485.714	COMPACTPLATY	
29	34.000	30.000	20.000	7.500	10681.414	801.106	0.732	1.600	441.176	COMPACTPLATY	
30	31.000	20.000	18.000	6.500	5843.359	486.947	0.805	1.417	419.355	COMPACTELONGATED	
31	28.000	20.000	19.000	7.500	5571.090	439.823	0.864	1.263	535.714	COMPACTELONGATED	
32	35.000	30.000	15.000	8.000	8246.680	824.668	0.598	2.167	457.143		PLATY
33	31.000	20.000	15.000	6.000	4869.465	486.947	0.713	1.700	387.097		ELONGATED
34	32.000	24.000	20.000	5.000	8042.477	603.186	0.805	1.400	312.500	COMPACTELONGATED	
35	30.000	27.000	24.000	3.500	10178.758	636.172	0.893	1.188	233.333	COMPACT	
36	28.000	22.000	20.000	2.000	6450.734	483.805	0.866	1.250	142.857	COMPACT	
37	34.000	26.000	19.000	4.500	8794.363	694.292	0.742	1.579	264.706	COMPACTBLADED	
38	27.000	25.000	24.000	6.000	8482.297	530.144	0.949	1.083	444.444	COMPACT	
39	30.000	28.000	25.000	3.000	10995.574	659.734	0.906	1.160	200.000	COMPACT	
40	25.000	20.000	15.000	4.500	3926.991	392.699	0.766	1.500	360.000	COMPACTBLADED	
41	28.000	27.000	22.000	3.000	8708.492	593.761	0.862	1.250	214.286	COMPACT	
42	34.000	31.000	25.000	2.000	13796.824	827.810	0.840	1.300	117.647	COMPACT	
43	29.000	25.000	15.000	2.500	5694.133	569.414	0.677	1.800	172.414	COMPACTPLATY	
44	35.000	30.000	16.000	4.500	8796.457	824.668	0.625	2.031	257.143		PLATY
45	38.000	32.000	30.000	2.000	19100.883	955.044	0.905	1.167	105.263	COMPACT	
46	34.000	30.000	23.000	3.500	12283.625	801.106	0.803	1.391	205.882	COMPACTBLADED	
47	25.000	23.000	20.000	9.000	6021.383	451.604	0.886	1.200	720.000	COMPACT	
48	27.000	25.000	15.000	7.500	5301.438	530.144	0.693	1.733	555.555	COMPACTPLATY	
49	30.000	22.000	15.000	3.500	5183.625	518.363	0.699	1.733	233.333		BLADED
50	28.000	26.000	19.000	9.500	7242.418	571.770	0.792	1.421	678.571	COMPACTPLATY	
51	26.000	23.000	20.000	6.000	6262.238	469.668	0.875	1.225	461.538	COMPACT	
52	36.000	26.000	20.000	7.500	9801.766	735.133	0.753	1.550	416.667	COMPACTBLADED	
53	34.000	32.000	22.000	8.000	12532.859	854.513	0.763	1.500	470.588	COMPACTPLATY	
54	38.000	37.000	34.000	2.000	25030.113	1104.270	0.937	1.103	105.263	COMPACT	
55	40.000	36.000	32.000	3.500	24127.430	1130.973	0.893	1.188	175.000	COMPACT	
56	27.000	25.000	22.000	9.500	7775.441	530.144	0.895	1.182	703.704	COMPACT	
57	40.000	34.000	30.000	4.000	21362.828	1068.141	0.871	1.233	200.000	COMPACT	
58	35.000	30.000	24.000	6.500	13194.688	824.668	0.819	1.354	371.428	COMPACTBLADED	
59	27.000	26.000	20.000	7.500	7351.324	551.349	0.829	1.325	555.555	COMPACT	
60	27.000	23.000	20.000	5.400	6503.094	487.732	0.864	1.250	400.000	COMPACT	
61	30.000	25.000	18.000	9.000	7068.582	589.049	0.756	1.528	600.000	COMPACTBLADED	
62	30.000	26.000	25.000	7.500	10210.176	612.610	0.929	1.120	500.000	COMPACT	
63	26.000	22.000	20.000	4.000	5989.969	449.248	0.888	1.200	307.692	COMPACT	
64	27.000	23.000	20.000	5.500	6503.094	487.732	0.864	1.250	407.407	COMPACT	
65	30.000	25.000	18.000	9.000	7068.582	589.049	0.756	1.528	600.000	COMPACTBLADED	
66	30.000	26.000	25.000	7.500	10210.176	612.610	0.929	1.120	500.000	COMPACT	
67	28.000	23.000	20.000	6.000	6743.949	505.796	0.853	1.275	428.571	COMPACT	
68	29.000	23.000	15.000	7.500	5238.605	523.860	0.696	1.733	517.241	COMPACTBLADED	
69	27.000	21.000	17.000	8.000	5046.965	445.321	0.799	1.412	592.593	COMPACTBLADED	
70	30.000	29.000	17.000	9.500	7744.023	683.296	0.693	1.735	633.333	COMPACTPLATY	
71	30.000	27.000	20.000	9.500	8482.297	636.172	0.790	1.425	633.333	COMPACTPLATY	
72	25.000	23.000	18.000	8.000	5419.246	451.604	0.826	1.333	640.000	COMPACT	
73	38.000	37.000	36.000	7.000	26502.473	1104.270	0.973	1.042	368.421	COMPACT	
74	38.000	30.000	20.000	4.500	11938.051	895.354	0.705	1.700	236.842	COMPACTBLADED	
75	31.000	30.000	25.000	6.000	12173.668	730.420	0.876	1.220	387.097	COMPACT	
76	38.000	30.000	25.000	7.500	14922.563	895.354	0.818	1.360	394.737	COMPACTBLADED	
77	44.000	35.000	30.000	9.000	24190.262	1209.513	0.836	1.317	409.091	COMPACTBLADED	
78	31.000	30.000	27.000	8.500	13147.563	730.420	0.922	1.130	548.387	COMPACT	
79	25.000	20.000	17.000	5.000	4450.586	392.699	0.833	1.324	400.000	COMPACTBLADED	
80	40.000	34.000	27.000	4.500	19226.547	1068.141	0.812	1.370	225.000	COMPACTBLADED	
81	31.000	25.000	24.000	3.000	9738.934	608.683	0.906	1.167	193.548	COMPACT	
82	27.000	25.000	24.000	2.500	8482.297	530.144	0.949	1.083	185.185	COMPACT	
83	25.000	23.000	20.000	9.500	6021.383	451.604	0.886	1.200	760.000	COMPACT	
84	32.000	30.000	25.000	9.000	12566.367	753.982	0.867	1.240	562.500	COMPACT	
85	40.000	34.000	20.000	8.500	14241.883	1068.141	0.665	1.850	425.000		PLATY
86	30.000	29.000	27.000	7.000	12299.332	683.296	0.943	1.093	466.667	COMPACT	
87	35.000	30.000	27.000	5.500	14844.023	824.668	0.885	1.204	314.286	COMPACT	
88	26.000	22.000	19.000	7.500	5690.469	449.248	0.858	1.263	576.923	COMPACT	
89	30.000	25.000	23.000	5.000	9032.078	589.049	0.890	1.196	333.333	COMPACT	
90	30.000	26.000	20.000	6.000	8168.141	612.610	0.800	1.400	400.000	COMPACTBLADED	
91	35.000	30.000	27.000	5.500	14844.023	824.668	0.885	1.204	314.286	COMPACT	
92	26.000	22.000	19.000	7.500	5690.469	449.248	0.858	1.263	576.923	COMPACT	
93	30.000	25.000	23.000	5.000	9032.078	589.049	0.890	1.196	333.333	COMPACT	
94	40.000	36.000	26.000	6.000	19603.535	1130.973	0.777	1.462	300.000	COMPACTPLATY	
95	32.000	30.000	25.000	7.500	12566.367	753.982	0.867	1.240	468.750	COMPACT	
96	34.000	30.000	15.000	5.000	8011.059	801.106	0.604	2.133	294.117		PLATY
97	29.000	27.000	19.000	3.500	7789.578	614.967	0.773	1.474	241.379	COMPACTPLATY	
98	43.000	31.000	30.000	8.000	20938.715	1046.936	0.877	1.233	372.093	COMPACTELONGATED	
99	38.000	36.000	32.000	8.500	22921.059	1074.425	0.908	1.156	447.368	COMPACT	
100	35.000	32.000	22.000	6.500	12901.473	879.646	0.756	1.523	371.428	COMPACTPLATY	

Table 103

Average roundness statistics of pebbles from fan FXI

Distance	$\bar{X}$	O_2	O	SK	K
200 m.	217.381	8189.141	90.494	1.924	9.662
700 m.	215.711	5960.621	77.205	0.879	2.852
1200 m.	252,065	8945.473	94.581	1.347	5.782
700 m.	254.064	9431.180	97.114	0.413	2.647
2200 m.	344.407	23495.199	153.281	0.513	2.681
Average	256.72		102.53		
				4.51	

Table 104

Average sphericity statistics of pebbles from fan FXI

Distance	$\bar{X}$	O_2	O	SK	K
200 m.	0.652	0.013	0.115	0.037	2.820
700 m.	0.765	0.013	0.114	-0.246	2.169
1200 m.	0.624	0.015	0.122	0.070	2.989
1700 m.	0.770	0.012	0.108	-0.793	3.245
2200 m.	0.778	0.014	0.120	-0.520	2.389
Average	0.71		0.11		
			52.00		

Table 105

Average roundness statistics of pebbles from fan FYII

Distance	$\overline{X}$	$\hat{\sigma}_2$	σ	SK	K
200 m.	231.828	6429.191	80.182	1.310	5.884
700 m.	248.909	4842.676	69.589	0.459	2.615
1200 m.	268.731	15043.977	122.654	0.673	2.965
1700 m.	370.831	20072.848	141.679	0.537	2.629
2200 m.	408.979	23895.926	154.583	0.115	2.287
Average	305.85		113.73		5.30

Table 106

Average sphericity statistics of pebbles from fan FYII

Distance	$\overline{X}$	$\hat{\sigma}_2$	σ	SK	K
200 m.	0.620	0.018	0.134	-0.016	2.115
700 m.	0.643	0.014	0.120	-0.004	2.094
1200 m.	0.699	0.028	0.169	-0.444	2.688
1700 m.	0.814	0.013	0.112	-1.034	4.036
2200 m.	0.831	0.008	0.087	-0.615	2.694
Average	0.71			0.12	-10.0

Table 107

Percentage of form class of pebbles from alluvial fans

	Distance	E %	V.E %	C.E %	Sub Total %	B %	V.B %	C.B %	Sub Total %	P %	V.P %	C.P %	Sub Total	Compact	Total
Fan (XI)	200 m.	21	11	14	46	17	13	10	40	9	1	2	12	2	100
	700 m.	1	0	12	13	9	0	22	31	12	0	18	30	26	100
	1200 m.	17	4	7	28	24	19	8	51	11	5	3	19	2	100
	1700 m.	2	0	13	15	5	0	24	29	9	3	18	30	26	100
	2200 m.	0	0	10	10	4	0	19	23	15	2	14	31	36	100
	%	8.2	3.0	11.2	22.4	11.8	6.4	16.6	34.8	11.2	2.2	11.0	24.4	18.4	100
	total	41	15	56	112	59	32	83	174	56	11	55	122	92	500
Fan (YII)	200 m.	18	6	7	31	23	18	4	45	6	8	5	19	5	100
	700 m.	19	6	15	40	19	16	7	42	9	6	2	17	1	100
	1200 m.	12	6	2	20	10	18	10	38	5	0	8	13	29	100
	1700 m.	1	0	7	8	2	0	14	16	4	3	18	25	51	100
	2200 m.	1	0	5	6	2	0	21	23	4	0	12	16	55	100
	%	10.2	3.6	7.2	21.0	11.2	10.4	11.2	32.8	5.6	3.4	9.0	18.0	28.2	100
	total	51	18	36	105	56	52	56	164	28	17	45	90	141	500

Table 108

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-1 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		6.31		-4	-25.24	100.96	-403.84	1615.36	3943.75
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	8.98		-3	-26.94	80.82	-242.46	727.38	2298.88
$\bar{1}$ - 0	$\bar{0}.5$	12.27		-2	-24.54	49.08	-98.16	196.32	993.87
0 - 1	0.5	20.97		-1	-20.97	20.97	-20.97	20.97	335.52
1 - 2	$\bar{X}_0$=1.5	22.37		0	0.00	0.00	0.00	0.00	22.37
2 - 3	2.5	16.45		1	16.45	16.45	16.45	16.45	0.00
3 - 4	3.5	10.48		2	20.96	41.92	83.84	167.68	10.48
4 - 5	4.5	1.59		3	4.77	14.31	42.93	128.79	25.44
5 - 6	5.5	0.23		4	0.92	3.68	14.72	58.88	18.63
6 - 7	6.5	0.09		5	0.45	2.25	11.25	56.25	23.04
7 - 8	7.5	0.08		6	0.48	2.88	17.28	103.68	50.00
8 - 9	8.5	0.18		7	1.26	8.82	61.74	432.18	233.28
$\bar{9}$		0.00		8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-52.40	342.14	-517.22	3523.94	7955.26
moments around the arbitrary origin					n_1 = -0.524	n_2 = 3.421	n_3 = -5.172	n_4 = 35.239	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_{\phi}$ = assumed mean M_{ϕ} = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness O_o = standard deviation   K = kurtosis $\overline{X}_o = 1.5$

$M_{\phi} = \frac{\Sigma fm}{\Sigma f} = 0.97$ $m_1 = X = X_o + cn_1 = 0.976$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.1465$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.0818$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 29.8069$ $\sigma_{\phi} = \sqrt{\sigma^2} = 1.7738$

$\sqrt{b_1} = \frac{m_3}{\sigma_{\phi}^3} = -0.0146$ $SK = \frac{\sqrt{b_1}}{2} = -0.0073$

$b_2 = \frac{m_4}{\sigma_{\phi}^4} = 3.0109$ $K = b_2 - 3 = 0.0109$

Summary: $\overline{X} = 0.976$ $M_{\phi} = 0.97$ $\sigma_{\phi} = 1.7738$ SK = 0.0073

$\sqrt{b_1} = -0.0146$ $b_2 = 3.0109$ K = 0.0109

Table 109

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-2 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		12.99		-3	-38.97	116.91	-350.73	1052.19	3325.44
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	17.04		-2	-34.08	68.16	-136.32	272.64	1380.24
$\bar{1}$ - 0	$\bar{0}.5$	15.40		-1	-15.40	15.40	-15.40	15.40	246.40
0 - 1	$\bar{X}_0$=0.5	19.92		0	0.00	0.00	0.00	0.00	19.92
1 - 2	1.5	17.79		1	17.79	17.79	17.79	17.79	0.00
2 - 3	2.5	9.47		2	18.94	37.88	75.76	151.52	9.47
3 - 4	3.5	5.46		3	16.38	49.14	147.42	442.26	87.36
4 - 5	4.5	1.39		4	5.56	22.24	88.96	355.84	112.59
5 - 6	5.5	0.39		5	1.95	9.75	48.75	243.75	99.84
6 - 7	6.5	0.01		6	0.06	0.36	2.16	12.96	6.25
7 - 8	7.5	0.05		7	0.35	2.45	17.15	120.05	64.80
8 - 9	8.5	0.09		8	0.72	5.76	46.08	368.64	216.09
$\bar{9}$		0.00		9	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-26.70	345.84	-58.38	3053.04	5568.40
moments around the arbitrary origin					n_1 = -0.267	n_2 = 3.458	n_3 = -0.584	n_4 = 30.53	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_{\phi}$ = assumed mean M_{ϕ} = logarithmetic mean c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_{ϕ} = standard deviation K = kurtosis $\overline{X}_o = 0.5$

$M_{\phi} = \frac{\Sigma fm}{\Sigma f} = 0.23$ $m_1 = X = X_o + cn_1 = 0.233$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.3868$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 2.1478$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 31.3685$ $\sigma_{\phi} = \sqrt{\sigma^2} = 1.8403$

$\sqrt{b_1} = \frac{m_3}{\sigma_{\phi}^3} = 0.3446$ $SK = \frac{\sqrt{b_1}}{2} = 0.1723$

$b_2 = \frac{m_4}{\sigma_{\phi}^4} = 2.7349$ $K = b_2 - 3 = -0.2651$

Summary: $\overline{X} = 0.233$ $M_{\phi} = 0.23$ $\sigma_{\phi} = 1.8403$ $SK = 0.1723$

$\sqrt{b_1} = 0.3446$ $b_2 = 2.7349$ $K = -0.2651$

Table 110

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-3 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		9.72		-4	-38.88	155.52	-622.08	2488.32	6075.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	16.93		-3	-50.79	152.37	-457.11	1371.33	4334.08
$\bar{1}$ - 0	$\bar{0}$.5	14.95		-2	-29.90	59.80	-119.60	239.20	1210.95
0 - 1	0.5	18.87		-1	-18.87	18.87	-18.87	18.87	301.92
1 - 2	$\bar{X}_o$=1.5	18.91		0	0.00	0.00	0.00	0.00	18.91
2 - 3	2.5	11.22		1	11.22	11.22	11.22	11.22	0.00
3 - 4	3.5	6.88		2	13.76	27.52	55.04	110.08	6.88
4 - 5	4.5	1.93		3	5.79	17.37	52.11	156.33	30.88
5 - 6	5.5	0.30		4	1.20	4.80	19.20	76.80	24.30
6 - 7	6.5	0.08		5	0.40	2.00	10.00	50.00	20.48
7 - 8	7.5	0.10		6	0.60	3.60	21.60	129.60	62.50
8 - 9	8.5	0.11		7	0.77	5.39	37.73	264.11	142.56
$\bar{9}$		0.00		8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-104.70	458.46	-1010.76	4915.86	12228.46
moments around the arbitrary origin					n_1 = -1.047	n_2 = 4.585	n_3 = -10.108	n_4 = 49.159	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.78 \qquad m_1 = X = X_o + cn_1 = 1.782$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.2445 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -2.6481$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 49.2935 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.0602$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.3028 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.1514$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.7362 \qquad K = b_2 - 3 = -0.2638$$

Summary: $\overline{X} = 1.782$ $M_\phi = 1.78$ $\sigma_\phi = 2.0602$ SK = 0.1514

$\sqrt{b_1} = -0.3028$ $b_2 = 2.7362$ K = -0.2638

Table 111

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-4 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		15.92		-1	-15.92	15.92	-15.92	15.92	254.72
$\bar{2}$ - $\bar{1}$	$X_o=\bar{1}.5$	19.87		0	0.00	0.00	0.00	0.00	19.87
$\bar{1}$ - 0	$\bar{0}.5$	14.87		1	14.87	14.87	14.87	14.87	0.00
0 - 1	0.5	16.72		2	33.44	66.88	133.76	267.52	16.72
1 - 2	1.5	15.25		3	45.75	137.25	411.75	1235.25	244.00
2 - 3	2.5	9.51		4	38.04	152.16	608.64	2434.56	770.31
3 - 4	3.5	6.00		5	30.00	150.00	750.00	3750.00	1536.00
4 - 5	4.5	1.48		6	8.88	53.28	319.68	1918.08	925.00
5 - 6	5.5	0.33		7	2.31	16.17	113.19	792.33	427.68
6 - 7	6.5	0.11		8	0.88	7.04	56.32	450.56	264.11
7 - 8	7.5	0.04		9	0.36	3.24	29.16	262.44	163.84
8 - 9	8.5	0.09		10	0.90	9.00	90.00	900.00	590.49
$\bar{9}$		0.00		11	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			159.51	625.81	2511.45	12041.53	5212.72
moments around the arbitrary origin					n_1 = 1.595	n_2 = 6.258	n_3 = 25.115	n_4 = 120.415	

m = midpoint of each class $\quad f$ = frequency $\quad \overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \overline{X}_o = -1.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.09$$

$$m_1 = X = X_o + cn_1 = 0.095$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.714$$

$$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 3.2857$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 36.2880$$

$$\sigma_\phi = \sqrt{\sigma^2} = 1.9271$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.4591$$

$$SK = \frac{\sqrt{b_1}}{2} = 0.2295$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.6312$$

$$K = b_2 - 3 = -0.3688$$

Summary: $\overline{X} = 0.095 \quad M_\phi = 0.09 \quad \sigma_\phi = 1.9271 \quad SK = 0.2295$

$\sqrt{b_1} = 0.4591 \quad b_2 = 2.6312 \quad K = -0.3688$

Table 112

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X5 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		2.60		-4	-10.40	41.60	-166.40	665.60	1625.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	2.05		-3	-6.15	18.45	-55.35	166.05	524.80
$\bar{1}$ - 0	$\bar{0}.5$	1.00		-2	-2.00	4.00	-8.00	16.00	81.00
0 - 1	0.5	16.32		-1	-16.32	16.32	-16.32	16.32	261.12
1 - 2	$\bar{X}_o$=1.5	29.97		0	0.00	0.00	0.00	0.00	29.97
2 - 3	2.5	19.05		1	19.05	19.05	19.05	19.05	0.00
3 - 4	3.5	23.96		2	47.92	95.84	191.68	383.36	23.96
4 - 5	4.5	4.77		3	14.31	42.93	128.79	386.37	76.32
5 - 6	5.5	0.10		4	0.40	1.60	6.40	25.60	8.10
6 - 7	6.5	0.02		5	0.10	0.50	2.50	12.50	5.12
7 - 8	7.5	0.01		6	0.06	0.36	2.16	12.96	6.25
8 - 9	8.5	0.11		7	0.77	5.39	37.73	264.11	142.56
9		0.00		8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			47.74	246.04	142.24	1967.92	2784.20
moments around the arbitrary origin					n_1 = 0.477	n_2 = 2.46	n_3 = 1.422	n_4 = 19.679	

m = midpoint of each class $\quad f$ = frequency $\quad \overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \overline{X}_o = 1.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.97 \qquad m_1 = X = X_o + cn_1 = 1.977$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.2325 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -1.8812$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 20.1687 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.4941$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.564 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.282$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.0474 \qquad K = b_2 - 3 = 1.0474$$

Summary: $\overline{X} = 1.977 \quad M_\phi = 1.97 \quad \sigma_\phi = 1.4941 \quad SK = -0.282$

$\sqrt{b_1} = -0.564 \quad b_2 = 4.0474 \quad K = 1.0474$

Table 113

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-6 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$		0.90		-6	-5.40	32.40	-194.40	1166.40	2160.90
$\overline{2}$ - $\overline{1}$	$\overline{1}.5$	0.79		-5	-3.95	19.75	-98.75	493.75	1023.84
$\overline{1}$ - 0	$\overline{0}.5$	1.23		-4	-4.92	19.68	-78.72	314.88	768.75
0 - 1	0.5	8.99		-3	-26.97	80.91	-242.73	728.19	2301.44
1 - 2	1.5	19.29		-2	-38.58	77.16	-154.32	308.64	1562.49
2 - 3	2.5	26.63		-1	-26.63	26.63	-26.63	26.63	426.08
3 - 4	$\overline{X}_0$=3.5	33.23		0	0.00	0.00	0.00	0.00	33.23
4 - 5	4.5	6.93		1	6.93	6.93	6.93	6.93	0.00
5 - 6	5.5	0.82		2	1.64	3.28	6.56	13.12	0.82
6 - 7	6.5	0.48		3	1.44	4.32	12.96	38.88	7.68
7 - 8	7.5	0.39		4	1.56	6.24	24.96	99.84	31.59
8 - 9	8.5	0.32		5	1.60	8.00	40.00	200.00	81.92
$\overline{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-93.28	285.30	-704.14	3397.26	8398.74
moments around the arbitrary origin					n_1 = -0.933	n_2 = 2.853	n_3 = 7.041	n_4 = 33.973	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.56 \qquad m_1 = X = X_o + cn_1 = 2.567$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 1.9826 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.6795$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 20.3230 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.408$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.2434 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.1217$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 5.1712 \qquad K = b_2 - 3 = 2.1712$$

Summary: $\bar{X} = 2.567$ $\quad$ $M_\phi = 2.56$ $\quad$ $\sigma_\phi = 1.408$ $\quad$ SK = -0.1217

$\sqrt{b_1} = -0.2434$ $\quad$ $b_2 = 5.1712$ $\quad$ K = 2.1712

Table 114

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-7 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		10.55		-3	-31.65	94.95	-284.85	854.55	2700.80
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	19.34		-2	-38.68	77.36	-154.72	309.44	1566.54
$\bar{1}$ - 0	$\bar{0}.5$	17.51		-1	-17.51	17.51	-17.51	17.51	280.16
0 - 1	$\bar{X}_0=0.5$	19.97		0	0.00	0.00	0.00	0.00	19.97
1 - 2	1.5	14.39		1	14.39	14.39	14.39	14.39	0.00
2 - 3	2.5	8.67		2	17.34	34.68	69.36	138.72	8.67
3 - 4	3.5	6.27		3	18.81	56.43	169.29	507.87	100.32
4 - 5	4.5	2.73		4	10.92	43.68	174.72	698.88	221.13
5 - 6	5.5	0.22		5	1.10	5.50	27.50	137.50	56.32
6 - 7	6.5	0.02		6	0.12	0.72	4.32	25.92	12.50
7 - 8	7.5	0.11		7	0.77	5.39	37.73	264.11	142.56
8 - 9	8.5	0.22		8	1.76	14.08	112.64	901.12	528.22
$\bar{9}$		0.00		9	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-22.63	364.69	152.87	3870.01	5637.19
moments around the arbitrary origin					$n_1 =$ -0.226	$n_2 =$ 3.647	$n_3 =$ 1.529	$n_4 =$ 38.7	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness 0_o = standard deviation   K = kurtosis $\overline{X}_o = 1.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.45$ $m_1 = X = X_o + cn_1 = 0.453$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.4888$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 1.9980$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 33.3783$ $\sigma_\phi = \sqrt{0^2} = 1.8678$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3066$ $SK = \frac{\sqrt{b_1}}{2} = 0.1533$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.7425$ $K = b_2 - 3 = -0.2575$

Summary: $\overline{X} = 0.453$ $M_\phi = 0.45$ $\sigma_\phi = 1.8678$ SK = 0.1533

$\sqrt{b_1} = 0.3066$ $b_2 = 2.7425$ K = -0.2575

Table 115

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-8 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		5.04		-6	-30.24	181.44	-1088.64	6531.84	12101.04
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	8.00		-5	-40.00	200.00	-1000.00	5000.00	10368.00
$\bar{1}$ - 0	$\bar{0}$.5	7.57		-4	-30.28	121.12	-484.48	1937.92	4731.25
0 - 1	0.5	12.95		-3	-38.85	116.55	-349.65	1048.95	3315.20
1 - 2	1.5	13.68		-2	-27.36	54.72	-109.44	218.88	1108.08
2 - 3	2.5	18.17		-1	-18.17	18.17	-18.17	18.17	290.72
3 - 4	$\bar{X}_o$=3.5	25.07		0	0.00	0.00	0.00	0.00	25.07
4 - 5	4.5	8.00		1	8.00	8.00	8.00	8.00	0.00
5 - 6	5.5	0.57		2	1.14	2.28	4.56	9.12	0.57
6 - 7	6.5	0.30		3	0.90	2.70	8.10	24.30	4.80
7 - 8	7.5	0.18		4	0.72	2.88	11.52	46.08	14.58
8 - 9	8.5	0.47		5	2.35	11.75	58.75	293.75	120.32
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	$\sum$	100			-171.79	719.61	-2959.45	15137.01	32079.63
moments around the arbitrary origin					n_1 = -1.718	n_2 = 7.196	n_3 = -29.595	n_4 = 151.37	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = 0.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.27 \qquad m_1 = X = X_o + cn_1 = 0.274$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.596 \qquad m_3 = c^3(n_3-3n_2n_1+2n_1^3) = 3.9786$$

$$m_4 = c^4(n_4-4n_3n_1+6n_1^2n_2-3n_1^4) = 41.1906 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.8963$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.5834 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.2917$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.1855 \qquad K = b_2 - 3 = 0.1855$$

Summary: $\overline{X} = 0.274$ $M_\phi = 0.27$ $\sigma_\phi = 1.8963$ SK = 0.2917

$\sqrt{b_1} = 0.5834$ $b_2 = 3.1855$ K = 0.1855

Table 116

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-9 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		3.85		-6	-23.10	138.60	-831.60	4989.60	9243.85
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	5.01		-5	-25.05	125.25	-626.25	3131.25	6492.96
$\bar{1}$ - 0	$\bar{0}$.5	6.57		-4	-26.28	105.12	-420.48	1681.92	4106.25
0 - 1	0.5	8.96		-3	-26.88	80.64	-241.92	725.76	2293.76
1 - 2	1.5	12.38		-2	-24.76	49.52	-99.04	198.08	1002.78
2 - 3	2.5	19.74		-1	-19.74	19.74	-19.74	19.74	315.84
3 - 4	$\bar{X}_0$=3.5	26.37		0	0.00	0.00	0.00	0.00	26.37
4 - 5	4.5	13.51		1	13.51	13.51	13.51	13.51	0.00
5 - 6	5.5	1.08		2	2.16	4.32	8.64	17.28	1.08
6 - 7	6.5	0.87		3	2.61	7.83	23.49	70.47	13.92
7 - 8	7.5	0.30		4	1.20	4.80	19.20	76.80	24.30
8 - 9	8.5	1.36		5	6.80	34.00	170.00	850.00	384.16
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-119.53	583.34	-2004.19	11774.41	23905.27
moments around the arbitrary origin					n_1 = -1.195	n_2 = 5.833	n_3 = -20.042	n_4 = 117.744	

m = midpoint of each class $\quad f$ = frequency $\quad \overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \overline{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.30 \qquad m_1 = X = X_o + cn_1 = 2.305$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.405 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -2.5435$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 65.8031 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.0988$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.2751 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.1375$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.3913 \qquad K = b_2 - 3 = 0.3913$$

Summary: $\overline{X} = 2.305$ $\quad M_\phi = 2.30$ $\quad \sigma_\phi = 2.0988$ $\quad SK = -0.1375$

$\sqrt{b_1} = -0.2751$ $\quad b_2 = 3.3913$ $\quad K = 0.3913$

Table 117

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-10 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		5.35	-13.37	-6	-32.1	192.60	-1155.60	6933.60	12845.35
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	8.45	-12.67	-5	-42.25	211.25	-1056.25	5281.25	10951.20
$\bar{1}$ - 0	$\bar{0}.5$	10.12	-5.06	-4	-40.48	161.92	-647.68	2590.72	6325.00
0 - 1	0.5	10.24	5.12	-3	-30.72	92.16	-276.48	829.44	2621.44
1 - 2	1.5	10.07	15.10	-2	-20.14	40.28	-80.56	161.12	815.67
2 - 3	2.5	17.00	42.50	-1	-17.00	17.00	-17.00	17.00	272.00
3 - 4	$\bar{X}_o$=3.5	27.16	95.06	0	0.00	0.00	0.00	0.00	27.16
4 - 5	4.5	5.04	22.68	1	5.04	5.04	5.04	5.04	0.00
5 - 6	5.5	3.00	16.50	2	6.00	12.00	24.00	48.00	3.00
6 - 7	6.5	1.00	6.50	3	3.00	9.00	27.00	81.00	16.00
7 - 8	7.5	1.00	7.50	4	4.00	16.00	64.00	256.00	81.00
8 - 9	8.5	0.50	4.25	5	2.50	12.50	62.50	312.50	128.00
$\bar{9}$		1.07	10.16	6	6.42	38.52	231.12	1386.72	668.75
Total	Σ	100	194.27		-155.73	808.27	-2819.91	17902.39	34754.57
moments around the arbitrary origin					n_1 = -1.557	n_2 = 8.083	n_3 = -28.199	n_4 = 179.024	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = 3.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 1.94 \qquad m_1 = X = X_o + cn_1 = 1.943$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 5.6588 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 2.0078$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 103.3394 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.3788$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.1491 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.0745$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.2273 \qquad K = b_2 - 3 = 0.2273$$

Summary: $\overline{X} = 1.943$ $M_\phi = 1.94$ $\sigma_\phi = 2.3788$ SK = 0.0745

$\sqrt{b_1} = 0.1491$ $b_2 = 3.2273$ K = 0.2273

Table 118

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-11 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		1.77		-6	-10.62	63.72	-382.32	2293.92	4249.77
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	4.28		-5	-21.40	107.00	-535.00	2675.00	5546.88
$\bar{1}$ - 0	$\bar{0}$.5	5.42		-4	-21.68	86.72	-346.52	1387.52	3387.50
0 - 1	0.5	8.08		-3	-24.24	72.72	-218.16	654.48	2068.48
1 - 2	1.5	10.01		-2	-20.02	40.04	-80.08	160.16	810.81
2 - 3	2.5	22.92		-1	-22.92	22.92	-22.92	22.92	366.72
3 - 4	$\bar{X}_o$=3.5	34.18		0	0.00	0.00	0.00	0.00	34.18
4 - 5	4.5	6.87		1	6.87	6.87	6.87	6.87	0.00
5 - 6	5.5	2.92		2	5.84	11.68	23.36	46.72	2.92
6 - 7	6.5	0.91		3	2.73	8.19	24.57	73.71	14.56
7 - 8	7.5	0.76		4	3.04	12.16	84.64	194.56	61.56
8 - 9	8.5	1.88		5	9.40	47.00	235.00	1175.00	481.28
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-93.00	479.02	-1210.56	8690.86	17024.66
moments around the arbitrary origin					n_1 = -0.93	n_2 = 4.79	n_3 = -12.106	n_4 = 86.909	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\overline{X}_o = 3.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.57$ $m_1 = X = X_o + cn_1 = 2.57$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.9251$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.3505$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 64.4882$ $\sigma_\phi = \sqrt{\sigma^2} = 1.9811$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.045$ $SK = \frac{\sqrt{b_1}}{2} = -0.0225$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.1866$ $K = b_2 - 3 = 1.1866$

Summary: $\overline{X} = 2.57$ $M_\phi = 2.57$ $\sigma_\phi = 1.9811$ SK = -0.0225

$\sqrt{b_1} = -0.045$ $b_2 = 4.1866$ K = 1.1866

Table 119

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-12 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\overline{2}$		1.71		-6	-10.26	61.56	-369.36	2216.16	4105.71
$\overline{2}$ - $\overline{1}$	$\overline{1}$.5	1.56		-5	-7.80	39.00	-195.00	975.00	2021.76
$\overline{1}$ - 0	$\overline{0}$.5	3.49		-4	-13.96	55.84	-223.36	893.44	2181.25
0 - 1	0.5	13.67		-3	-41.01	123.03	-369.09	1107.27	3499.52
1 - 2	1.5	12.61		-2	-25.22	50.44	-100.88	201.76	1021.41
2 - 3	2.5	20.87		-1	-20.87	20.87	-20.87	20.87	333.92
3 - 4	$\overline{X}_0$=3.5	37.52		0	0.00	0.00	0.00	0.00	37.52
4 - 5	4.5	6.04		1	6.04	6.04	6.04	6.04	0.00
5 - 6	5.5	1.13		2	2.26	4.52	9.04	18.08	1.13
6 - 7	6.5	0.28		3	0.84	2.52	7.56	22.68	4.48
7 - 8	7.5	0.10		4	0.40	1.60	6.40	25.60	8.10
8 - 9	8.5	1.02		5	5.10	25.50	127.50	637.50	261.12
$\overline{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ				-104.48	390.92	-1149.02	6124.36	13475.92
moments around the arbitrary origin					n_1 = -1.045	n_2 = 3.909	n_3 = -11.49	n_4 = 61.244	

m = midpoint of each class   f = frequency $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.45 \qquad m_1 = X = X_o + cn_1 = 2.455$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.817 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -1.5175$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 35.2503 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.6783$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.321 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.1605$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.4433 \qquad K = b_2 - 3 = 1.4433$$

Summary: $\bar{X} = 2.455$ $M_\phi = 2.45$ $\sigma_\phi = 1.6783$ SK = -0.1605

$\sqrt{b_1} = -0.321$ $b_2 = 4.4433$ K = 1.4433

Table 120

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-13 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.34		-6	-2.04	12.24	-73.44	440.64	816.34
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.85		-5	-4.25	21.25	-106.25	531.25	1101.60
$\bar{1}$ - 0	$\bar{0}$.5	3.13		-4	-12.52	50.08	-200.32	801.28	1956.25
0 - 1	0.5	7.75		-3	-23.25	69.75	-209.25	627.75	1984.00
1 - 2	1.5	12.17		-2	-24.34	48.68	-97.36	194.72	985.77
2 - 3	2.5	26.52		-1	-26.52	26.52	-26.52	26.52	424.32
3 - 4	$\bar{X}_o$=3.5	37.97		0	0.00	0.00	0.00	0.00	37.97
4 - 5	4.5	5.95		1	5.95	5.95	5.95	5.95	0.00
5 - 6	5.5	4.26		2	8.52	17.04	34.08	68.16	4.26
6 - 7	6.5	0.61		3	1.83	5.49	16.47	49.41	9.76
7 - 8	7.5	0.37		4	1.48	5.92	23.68	94.72	29.97
8 - 9	8.5	0.08		5	0.40	2.00	10.00	50.00	20.48
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-74.74	264.92	-622.96	2890.40	7370.72
moments around the arbitrary origin					n_1 = -0.747	n_2 = 2.649	n_3 = -6.23	n_4 = 28.904	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_o$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\overline{X}_o = 3.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.75$ $m_1 = X = X_o + cn_1 = 2.753$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.091$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -1.1272$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 18.2237$ $\sigma_\phi = \sqrt{\sigma^2} = 1.446$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.3728$ $SK = \frac{\sqrt{b_1}}{2} = -0.1864$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.1684$ $K = b_2 - 3 = 1.1684$

Summary: $\overline{X} = 2.753$ $M_\phi = 2.75$ $\sigma_\phi = 1.446$ SK = -0.1864

$\sqrt{b_1} = -0.3728$ $b_2 = 4.1684$ K = 1.1684

Table 121

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-14 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		2.18		-6	-13.08	78.48	-470.88	2825.28	5234.18
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.55		-5	-2.75	13.75	-68.75	343.75	712.80
$\bar{1}$ - 0	$\bar{0}.5$	1.54		-4	-6.16	24.64	-98.56	394.24	962.50
0 - 1	0.5	8.15		-3	-24.45	73.35	-220.05	660.15	2086.40
1 - 2	1.5	15.96		-2	-31.92	63.84	-127.68	255.36	1292.76
2 - 3	2.5	29.06		-1	-29.06	29.06	-29.06	29.06	464.96
3 - 4	$\bar{X}_o$=3.5	34.72		0	0.00	0.00	0.00	0.00	34.72
4 - 5	4.5	4.70		1	4.70	4.70	4.70	4.70	0.00
5 - 6	5.5	2.05		2	4.10	8.20	16.40	32.80	2.05
6 - 7	6.5	0.59		3	1.77	5.31	15.93	47.76	9.44
7 - 8	7.5	0.20		4	0.80	3.20	12.80	51.20	16.20
8 - 9	8.5	0.30		5	1.50	7.50	37.50	187.50	76.80
$\bar{9}$		0.00		6	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-94.55	312.03	-927.65	4831.80	10892.63
moments around the arbitrary origin					n_1 = -0.946	n_2 = 3.12	n_3 = -9.277	n_4 = 48.318	

m = midpoint of each class $\quad f$ = frequency $\quad \bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \quad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \quad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \quad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \bar{X}_o = 3.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma f} = 2.55 \qquad m_1 = X = X_o + cn_1 = 2.554$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.2251 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -2.1155$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 27.5643 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.4916$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.6374 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.3187$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 5.5687 \qquad K = b_2 - 3 = 2.5687$$

Summary: $\bar{X} = 2.554 \quad M_\phi = 2.55 \quad \sigma_\phi = 1.4916 \quad SK = -0.3187$

$\sqrt{b_1} = -0.6374 \quad b_2 = 5.5687 \quad K = 2.5687$

Table 122

Computation of Statistics from the first moments of a frequency distribution of a Sample No. X-15 from fan FX-1 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		2.13		-5	-10.65	53.25	-266.25	1331.25	2760.48
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.82		-4	-3.28	13.12	-52.48	209.92	512.50
$\bar{1}$ - 0	$\bar{0}$.5	1.48		-3	-4.44	13.32	-39.96	119.88	378.88
0 - 1	0.5	10.38		-2	-20.76	41.52	-83.04	166.08	840.78
1 - 2	1.5	19.86		-1	-19.86	19.86	-19.86	19.86	317.76
2 - 3	$\bar{X}_0$=2.5	30.72		0	0.00	0.00	0.00	0.00	30.72
3 - 4	3.5	28.84		1	28.84	28.84	28.84	28.84	0.00
4 - 5	4.5	4.40		2	8.80	17.60	35.20	70.40	4.40
5 - 6	5.5	0.84		3	2.52	7.56	22.68	68.04	13.44
6 - 7	6.5	0.20		4	0.80	3.20	12.80	51.20	16.20
7 - 8	7.5	0.13		5	0.65	3.25	16.25	81.25	33.28
8 - 9	8.5	0.20		6	1.20	7.20	43.20	259.20	125.00
$\bar{9}$		0.00		7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-16.18	208.72	-302.62	2405.92	5033.44
moments around the arbitrary origin					n_1 = -0.162	n_2 = 2.087	n_3 = -3.026	n_4 = 24.059	

m = midpoint of each class $\quad f$ = frequency $\quad \bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \bar{X}_o = 2.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.33 \qquad m_1 = X = X_o + cn_1 = 2.338$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.0608 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -2.0202$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 22.4244 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.4355$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.6829 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.3414$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 5.2813 \qquad K = b_2 - 3 = 2.2813$$

Summary: $\bar{X} = 2.338 \quad M_\phi = 2.33 \quad \sigma_\phi = 1.4355 \quad SK = -0.3414$

$\sqrt{b_1} = -0.6829 \quad b_2 = 5.2813 \quad K = 2.2813$

Table 123

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y-1 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		16.78	-41.95	-1	-16.78	16.78	-16.78	16.78	268.48
$\bar{2}$ - $\bar{1}$	$X_0=\bar{1}.5$	21.36	-32.04	0	0.00	0.00	0.00	0.00	21.36
$\bar{1}$ - 0	$\bar{0}.5$	19.48	-9.74	1	19.48	19.48	19.48	19.48	0.00
0 - 1	0.5	14.01	7.00	2	28.02	56.04	112.08	224.16	14.01
1 - 2	1.5	11.72	17.58	3	35.16	105.48	316.44	949.32	187.52
2 - 3	2.5	7.76	19.40	4	31.04	124.16	496.64	1986.56	628.56
3 - 4	3.5	5.78	20.23	5	28.90	144.50	722.50	3612.50	1479.68
4 - 5	4.5	0.14	0.63	6	0.84	5.04	30.24	181.44	87.50
5 - 6	5.5	0.91	5.00	7	6.37	44.59	312.13	2184.91	1179.36
6 - 7	6.5	2.06	19.57	8	16.48	131.84	1054.72	8437.76	4946.06
7 - 8	7.5	0.00	0.00	9	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	10	0.00	0.00	0.00	0.00	0.00
$\bar{9}$		0.00	0.00	11	0.00	0.00	0.00	0.00	0.00
Total	Σ		5.68		149.51	647.91	3047.45	17612.91	8812.53
moments around the arbitrary origin					$n_1 =$ 1.495	$n_2 =$ 6.479	$n_3 =$ 30.475	$n_4 =$ 176.129	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis X_o = -1.5

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.05$ $m_1 = X = X_o + cn_1 = -0.005$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.244$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 8.0993$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 65.7862$ $\sigma_\phi = \sqrt{\sigma^2} = 2.06$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.9265$ $SK = \frac{\sqrt{b_1}}{2} = 0.4632$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.6531$ $K = b_2 - 3 = 0.6531$

Summary: $\overline{X}$ = -0.005 M_ϕ = 0.05 σ_ϕ = 2.06   SK = 0.4632

$\sqrt{b_1}$ = 0.9265 b_2 = 3.6531   K = 0.6531

Table 124

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y-2 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		12.12		-5	-60.60	303.00	-1515.00	7575.00	15707.52
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	17.01		-4	-68.04	272.16	-1088.64	4354.56	10631.25
$\bar{1}$ - 0	$\bar{0}$.5	12.00		-3	-36.00	108.00	-324.00	972.00	3072.00
0 - 1	0.5	12.15		-2	-24.30	48.60	-97.20	194.40	984.15
1 - 2	1.5	12.49		-1	-12.49	12.49	-12.49	12.49	199.84
2 - 3	$\bar{X}_0$=2.5	21.58		0	0.00	0.00	0.00	0.00	21.58
3 - 4	3.5	11.08		1	11.08	11.08	11.08	11.08	0.00
4 - 5	4.5	1.38		2	2.76	5.52	11.04	22.08	1.38
5 - 6	5.5	0.09		3	0.27	0.81	2.43	7.29	1.44
6 - 7	6.5	0.04		4	0.16	0.64	2.56	10.24	3.24
7 - 8	7.5	0.01		5	0.05	0.25	1.25	6.25	2.56
8 - 9	8.5	0.05		6	0.30	1.80	10.80	64.80	31.25
$\bar{9}$		0.00		7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			-186.81	764.35	-2998.17	13230.19	30656.21
moments around the arbitrary origin					n_1 = -1.868	n_2 = 7.644	n_3 = -29.982	n_4 = 132.302	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_{\phi}$ = assumed mean $\quad$ M_{ϕ} = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad$ σ_{ϕ} = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 2.5$

$$M_{\phi} = \frac{\Sigma fm}{\Sigma f} = 0.63 \qquad m_1 = X = X_o + cn_1 = 0.632$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.1546 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -0.1813$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 31.7869 \qquad \sigma_{\phi} = \sqrt{\sigma^2} = 2.0382$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_{\phi}^3} = -0.0214 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.0107$$

$$b_2 = \frac{m_4}{\sigma_{\phi}^4} = 1.8419 \qquad K = b_2 - 3 = -1.1581$$

Summary: $\bar{X} = 0.632$ $\quad$ $M_{\phi} = 0.63$ $\quad$ $\sigma_{\phi} = 2.0382$ $\quad$ $SK = -0.0107$

$\sqrt{b_1} = -0.0214$ $\quad$ $b_2 = 1.8419$ $\quad$ $K = -1.1581$

Table 125

Computation of Statistics from the first moments of a frequency distribution of a sample No. Y3 from fan FY-II east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-3	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.43	-0.64	-2	-0.86	1.72	-3.44	6.88	34.83
$\bar{1}$ - 0	$\bar{0}.5$	11.24	-5.62	-1	-11.24	11.24	-11.24	11.24	179.84
0 - 1	$\bar{X}_o$=0.5	66.80	33.40	0	0.00	0.00	0.00	0.00	66.80
1 - 2	1.5	12.59	18.88	1	12.59	12.59	12.59	12.59	0.00
2 - 3	2.5	3.74	9.35	2	7.48	14.96	29.92	59.84	3.74
3 - 4	3.5	1.32	4.62	3	3.96	11.88	35.64	106.92	21.12
4 - 5	4.5	0.81	3.64	4	3.24	12.96	51.84	207.36	65.61
5 - 6	5.5	0.87	4.78	5	3.90	19.50	97.50	487.50	199.68
6 - 7	6.5	0.43	2.80	6	2.58	15.48	92.88	557.28	268.75
7 - 8	7.5	1.79	13.42	7	12.39	86.73	607.11	4249.77	2293.92
8 - 9	8.5	0.00	0.00	8	0.00	0.00	0.00	0.00	0.00
9		0.00	0.00	9	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	84.63		34.04	187.06	912.80	5699.38	3134.29
moments around the arbitrary origin					n_1 = 0.34	n_2 = 1.871	n_3 = 9.128	n_4 = 56.994	

m = midpoint of each class $\quad f$ = frequency $\quad \overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma fd}{\Sigma f} \qquad n_2 = \frac{\Sigma fd^2}{\Sigma f} \qquad n_3 = \frac{\Sigma fd^3}{\Sigma f} \qquad n_4 = \frac{\Sigma fd^4}{\Sigma f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \overline{X}_o = 0.5$

$$M_\phi = \frac{\Sigma fm}{\Sigma f} = 0.846 \qquad m_1 = X = X_o + cn_1 = 0.84$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 1.7554 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 7.2982$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 45.8378 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.3249$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 3.1383 \qquad SK = \frac{\sqrt{b_1}}{2} = 1.5691$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 14.8775 \qquad K = b_2 - 3 = 11.8775$$

Summary: $\overline{X} = 0.84 \quad M_\phi = 0.84 \quad \sigma_\phi = 1.3249 \quad SK = 1.5691$

$\sqrt{b_1} = 3.1383 \quad b_2 = 14.8775 \quad K = 11.8775$

Table 126

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y4 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-4	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-3	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	1.20	-0.60	-2	-2.40	4.80	-9.60	19.20	97.20
0 - 1	0.5	32.70	16.35	-1	-32.70	32.70	-32.70	32.70	523.20
1 - 2	X_o=1.5	38.70	58.05	0	0.00	0.00	0.00	0.00	38.70
2 - 3	2.5	16.20	40.50	1	16.20	16.20	16.20	16.20	0.00
3 - 4	3.5	9.95	34.82	2	19.90	39.80	79.60	159.20	9.95
4 - 5	4.5	1.25	5.62	3	3.75	11.25	33.75	101.25	20.00
5 - 6	5.5	0.00	0.00	4	0.00	0.00	0.00	0.00	0.00
6 - 7	6.5	0.00	0.00	5	0.00	0.00	0.00	0.00	0.00
7 - 8	7.5	0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
9		0.00	0.00	8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	154.74		4.75	104.75	129.55	328.55	689.05
moments around the arbitrary origin					n_1 = 0.048	n_2 = 1.048	n_3 = 1.296	n_4 = 3.286	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f}$ $n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f}$ $n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f}$ $n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 1.5$

$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 1.54$ $m_1 = X = X_o + cn_1 = 1.548$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 1.0457$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 1.1453$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 3.0516$ $\sigma_\phi = \sqrt{\sigma^2} = 1.0225$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 1.0713$ $SK = \frac{\sqrt{b_1}}{2} = 0.5356$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.7919$ $K = b_2 - 3 = -0.2081$

Summary: $\overline{X} = 1.548$ $M_\phi = 0.84$ $\sigma_\phi = 1.3249$ SK = 1.5691

$\sqrt{b_1} = 1.0713$ $b_2 = 2.7919$ $K = -0.2081$

Table 127

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y5 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-4	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.00	0.00	-3	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}$.5	0.23	-0.11	-2	-0.46	0.92	-1.84	3.68	18.63
0 - 1	0.5	9.54	4.77	-1	-9.54	9.54	-9.54	9.54	152.64
1 - 2	X_o=1.5	48.22	72.33	0	0.00	0.00	0.00	0.00	48.22
2 - 3	2.5	27.53	68.82	1	27.53	27.53	27.53	27.53	0.00
3 - 4	3.5	13.71	47.98	2	27.42	54.84	109.68	219.36	13.71
4 - 5	4.5	0.77	3.46	3	2.31	6.93	20.79	62.37	12.32
5 - 6	5.5	0.00	0.00	4	0.00	0.00	0.00	0.00	0.00
6 - 7	6.5	0.00	0.00	5	0.00	0.00	0.00	0.00	0.00
7 - 8	7.5	0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
$\bar{9}$		0.00	0.00	8	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	197.25		47.26	99.76	146.62	322.48	245.52
moments around the arbitrary origin					n_1 = 0.473	n_2 = 0.998	n_3 = 1.466	n_4 = 3.225	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_o$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $\quad$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $\quad$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $\quad$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $X_o = 1.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 1.97$ $\quad$ $m_1 = X = X_o + cn_1 = 1.973$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 0.7743$ $\quad$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.2615$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 1.6409$ $\quad$ $\sigma_\phi = \sqrt{\sigma^2} = 0.8799$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.3838$ $\quad$ $SK = \frac{\sqrt{b_1}}{2} = 0.1919$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.738$ $\quad$ $K = b_2 - 3 = -0.262$

Summary: $\bar{X} = 1.973$ $\quad$ $M_\phi = 1.97$ $\quad$ $\sigma_\phi = 0.8799$ $\quad$ SK = 0.1919

$\sqrt{b_1} = 0.3838$ $\quad$ $b_2 = 2.738$ $\quad$ K = -0.262

Table 128

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y6 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-5	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-4	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	1.68	-0.84	-3	-5.04	15.12	-45.36	136.08	430.08
0 - 1	0.5	12.04	6.02	-2	-24.08	48.16	-96.32	192.64	975.24
1 - 2	1.5	27.07	40.60	-1	-27.07	27.07	-27.07	27.07	433.12
2 - 3	$\bar{X}_o$=2.5	32.45	81.12	0	0.00	0.00	0.00	0.00	32.45
3 - 4	3.5	24.47	85.64	1	24.47	24.47	24.47	24.47	0.00
4 - 5	4.5	1.72	7.74	2	3.44	6.88	13.76	27.52	1.72
5 - 6	5.5	0.24	1.32	3	0.72	2.16	6.48	19.44	3.84
6 - 7	6.5	0.57	3.71	4	2.28	9.12	36.48	145.92	46.17
7 - 8	7.5	0.00	0.00	5	0.00	0.00	0.00	0.00	0.00
8 - 9	8.5	0.00	0.00	6	0.00	0.00	0.00	0.00	0.00
9		0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	225.87		-25.28	132.98	-87.56	573.14	1922.62
moments around the arbitrary origin					n_1 = -0.253	n_2 = 1.33	n_3 = -0.876	n_4 = 5.731	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_{\phi}$ = assumed mean M_{ϕ} = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness σ_{ϕ} = standard deviation K = kurtosis $\overline{X}_o = 2.5$

$$M_{\phi} = \frac{\Sigma\ fm}{\Sigma\ f} = 2.258 \qquad m_1 = X = \overline{X}_o + cn_1 = 2.247$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 1.266 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.1012$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 5.3432 \qquad \sigma_{\phi} = \sqrt{\sigma^2} = 1.1251$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_{\phi}^3} = 0.071 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.0355$$

$$b_2 = \frac{m_4}{\sigma_{\phi}^4} = 3.3349 \qquad K = b_2 - 3 = 0.3349$$

Summary: $\overline{X} = 2.247$ $M_{\phi} = 2.25$ $\sigma_{\phi} = 1.1251$ SK = 0.0355

$\sqrt{b_1} = 0.071$ $b_2 = 3.3349$ K = 0.3349

Table 129

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y7 from fan FY-11 east of Jebal Umm ad Dabah.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		11.59	-28.97	-6	-69.54	417.24	-2503.44	15020.64	27827.59
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	4.85	-7.27	-5	-24.25	121.25	-606.25	3031.25	6285.60
$\bar{1}$ - 0	$\bar{0}$.5	2.89	-1.44	-4	-11.56	46.24	-184.96	739.84	1806.25
0 - 1	0.5	6.52	3.26	-3	-19.56	58.68	-176.04	528.12	1669.12
1 - 2	1.5	11.76	17.64	-2	-23.52	47.04	-94.08	188.16	952.56
2 - 3	2.5	15.63	39.07	-1	-15.63	15.63	-15.63	15.63	250.08
3 - 4	X_o=3.5	22.39	78.36	0	0.00	0.00	0.00	0.00	22.39
4 - 5	4.5	10.13	45.58	1	10.13	10.13	10.13	10.13	0.00
5 - 6	5.5	9.75	53.62	2	19.50	39.00	78.00	156.00	9.75
6 - 7	6.5	0.88	5.72	3	2.64	7.92	23.76	71.28	14.08
7 - 8	7.5	1.77	13.27	4	7.08	28.32	113.28	453.12	143.37
8 - 9	8.5	0.44	3.74	5	2.20	11.00	55.00	275.00	112.64
9		1.84	17.48	6	11.04	66.24	397.44	2384.64	1150.00
Total	Σ	100	240.06		-111.47	868.69	-2902.79	22873.81	40243.43
moments around the arbitrary origin					n_1 = -1.115	n_2 = 8.687	n_3 = -29.028	n_4 = 228.738	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 3.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.40$

$m_1 = X = X_o + cn_1 = 2.385$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.4438$

$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -2.7422$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 159.4347$

$\sigma_\phi = \sqrt{\sigma^2} = 2.7283$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.135$

$SK = \frac{\sqrt{b_1}}{2} = -0.0675$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.8775$

$K = b_2 - 3 = -0.1225$

Summary: $\overline{X} = 2.385$ $M_\phi = 2.40$ $\sigma_\phi = 2.7283$ SK = -0.0675

$\sqrt{b_1} = -0.135$ $b_2 = 2.8775$ K = -0.1225

Table 130

Computation of Statistics from the first moments of a frequency distribution of a sample No. Y8 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-4	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.34	-0.50	-3	-1.02	3.06	-9.18	27.54	87.04
$\bar{1}$ - 0	$\bar{0}.5$	0.71	-0.35	-2	-1.42	2.84	-5.68	11.36	57.51
0 - 1	0.5	11.18	5.59	-1	-11.18	11.18	-11.18	11.18	178.88
1 - 2	X_o=1.5	31.50	47.25	0	0.00	0.00	0.00	0.00	31.50
2 - 3	2.5	15.39	38.47	1	15.39	15.39	15.39	15.39	0.00
3 - 4	3.5	15.25	53.37	2	30.50	61.00	122.00	244.00	15.25
4 - 5	4.5	14.19	63.85	3	42.57	127.71	383.13	1149.39	227.04
5 - 6	5.5	2.36	15.34	4	9.44	37.76	151.04	604.16	191.16
6 - 7	6.5	1.77	11.50	5	8.85	44.25	221.25	1106.25	453.12
7 - 8	7.5	2.36	17.70	6	14.16	84.96	509.76	3058.56	1475.00
8 - 9	8.5	1.18	10.03	7	8.26	57.82	404.74	2833.18	1529.28
9		3.77	35.81	8	30.16	241.28	1930.24	15441.92	9051.77
Total	Σ	100	298.05		145.71	687.25	3711.51	24502.93	13297.55
moments around the arbitrary origin					n_1 = 1.457	n_2 = 6.873	n_3 = 37.115	n_4 = 245.029	

m = midpoint of each class f = frequency $\bar{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $X_o = 1.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 2.98 \qquad m_1 = X = X_o + cn_1 = 2.957$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.7502 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 13.2590$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 102.7439 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.1794$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 1.2808 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.6404$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 4.5542 \qquad K = b_2 - 3 = 1.5542$$

Summary: $\bar{X} = 2.957$ $M_\phi = 2.98$ $\sigma_\phi = 2.1794$ SK = 0.6404

$\sqrt{b_1} = 1.2808$ $b_2 = 4.5542$ K = 1.5542

Table 131

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y9 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		2.22		-5	-11.10	55.50	-277.50	1387.50	2877.12
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	1.97		-4	-7.88	31.52	-126.08	504.32	1231.25
$\bar{1}$ - 0	$\bar{0}.5$	1.69		-3	-5.07	15.21	-45.63	136.89	432.64
0 - 1	0.5	5.08		-2	-10.16	20.32	-40.64	81.28	411.48
1 - 2	1.5	21.90		-1	-21.90	21.90	-21.90	21.90	350.40
2 - 3	X_o=2.5	24.87		0	0.00	0.00	0.00	0.00	24.87
3 - 4	3.5	18.14		1	18.14	18.14	18.14	18.14	0.00
4 - 5	4.5	7.37		2	14.74	29.48	58.96	117.92	7.37
5 - 6	5.5	2.76		3	8.28	24.84	74.52	223.56	44.16
6 - 7	6.5	2.46		4	9.84	39.36	157.44	629.76	199.26
7 - 8	7.5	1.69		5	8.45	42.25	211.25	1056.25	432.64
8 - 9	8.5	9.85		6	59.10	354.60	2127.60	12765.60	6156.25
9		0.00		7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100			62.44	833.12	2136.16	16943.12	12167.44
moments around the arbitrary origin					n_1 = 0.624	n_2 = 8.331	n_3 = 21.362	n_4 = 169.431	

m = midpoint of each class $\qquad$ f = frequency $\qquad$ $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean $\qquad$ M_ϕ = logarithmetic mean $\qquad$ c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness $\qquad$ σ_ϕ = standard deviation $\qquad$ K = kurtosis $\qquad$ $\overline{X}_o = 2.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 3.12 \qquad m_1 = X = X_o + cn_1 = 3.124$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 7.9417 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 6.2522$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 135.1165 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.8181$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.2793 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.1396$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.1423 \qquad K = b_2 - 3 = -0.8577$$

Summary: $\overline{X} = 3.124$ $\qquad$ $M_\phi = 3.12$ $\qquad$ $\sigma_\phi = 2.8181$ $\qquad$ SK = 0.1396

$\sqrt{b_1} = 0.2793$ $\qquad$ $b_2 = 2.1423$ $\qquad$ K = -0.8577

Table 132

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y10 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-5	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	0.83	-1.24	-4	-3.32	13.28	-53.12	212.48	518.75
$\bar{1}$ - 0	$\bar{0}$.5	2.64	-1.32	-3	-7.92	23.76	-71.28	213.84	675.84
0 - 1	0.5	6.78	3.39	-2	-13.56	27.12	-54.24	108.48	549.18
1 - 2	1.5	22.57	33.85	-1	-22.57	22.57	-22.57	22.57	361.12
2 - 3	2.5	33.73	84.32	0	0.00	0.00	0.00	0.00	33.73
3 - 4	3.5	23.78	83.23	1	23.78	23.78	23.78	23.78	0.00
4 - 5	4.5	4.62	20.79	2	9.24	18.48	36.96	73.92	4.62
5 - 6	5.5	1.50	8.25	3	4.50	13.50	40.50	121.50	24.00
6 - 7	6.5	0.50	3.25	4	2.00	8.00	32.00	128.00	40.50
7 - 8	7.5	1.00	7.50	5	5.00	25.00	125.00	625.00	256.00
8 - 9	8.5	2.05	17.43	6	12.30	73.80	442.80	2656.80	1281.25
$\bar{9}$	9.50	0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	259.44		9.45	249.29	499.83	4186.37	3744.99
moments around the arbitrary origin					n_1 = 0.095	n_2 = 2.493	n_3 = 4.998	n_4 = 41.864	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\bar{X}$ = arithmetic mean

$\bar{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f}$ $\quad$ $n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f}$ $\quad$ $n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f}$ $\quad$ $n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\bar{X}_o = 2.5$

$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 2.59$ $\quad$ $m_1 = X = X_o + cn_1 = 2.595$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.484$ $\quad$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 4.2891$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 40.0994$ $\quad$ $\sigma_\phi = \sqrt{\sigma^2} = 1.576$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 1.0957$ $\quad$ $SK = \frac{\sqrt{b_1}}{2} = 0.5478$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 6.5002$ $\quad$ $K = b_2 - 3 = 3.5002$

Summary: $\bar{X} = 2.595$ $\quad$ $M_\phi = 2.59$ $\quad$ $\sigma_\phi = 1.576$ $\quad$ SK = 0.5478

$\sqrt{b_1} = 1.0957$ $\quad$ $b_2 = 6.5002$ $\quad$ $K = 3.5002$

Table 133

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y11 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		3.80	-9.50	-5	-19.00	95.00	-475.00	2375.00	4924.80
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	2.18	-3.27	-4	-8.72	34.88	-139.52	558.08	1362.50
$\bar{1}$ - 0	$\bar{0}.5$	1.98	-0.99	-3	-5.94	17.82	-53.46	160.38	506.88
0 - 1	0.5	4.02	2.01	-2	-8.04	16.08	-32.16	64.32	325.62
1 - 2	1.5	13.76	20.64	-1	-13.76	13.76	-13.76	13.76	220.16
2 - 3	X_0=2.5	21.41	53.52	0	0.00	0.00	0.00	0.00	21.41
3 - 4	3.5	17.96	62.86	1	17.96	17.96	17.96	17.96	0.00
4 - 5	4.5	19.45	87.52	2	38.90	77.80	155.60	311.20	19.45
5 - 6	5.5	5.91	32.50	3	17.73	53.19	159.57	478.71	94.56
6 - 7	6.5	1.97	12.80	4	7.88	31.52	126.08	504.32	159.57
7 - 8	7.5	1.97	14.77	5	9.85	49.25	246.25	1231.25	504.32
8 - 9	8.5	0.98	8.33	6	5.88	35.28	211.68	1270.08	612.50
$\bar{9}$		4.61	43.79	7	32.27	225.89	1581.23	11068.61	5974.56
Total	Σ	100	324.98		75.01	668.43	1784.47	18053.67	14726.33
moments around the arbitrary origin					n_1 = 0.75	n_2 = 6.684	n_3 = 17.845	n_4 = 180.537	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma\ fd}{\Sigma\ f}$ $n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f}$ $n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f}$ $n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $X_o = 2.5$

$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 3.25$ $m_1 = X = X_o + cn_1 = 3.25$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 6.1215$ $m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 3.6496$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 148.6116$ $\sigma_\phi = \sqrt{\sigma^2} = 2.4741$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.2409$ $SK = \frac{\sqrt{b_1}}{2} = 0.1204$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.9663$ $K = b_2 - 3 = 0.9663$

Summary: $\overline{X} = 3.25$ $M_\phi = 3.25$ $\sigma_\phi = 2.4741$ SK = 0.1204

$\sqrt{b_1} = 0.2409$ $b_2 = 3.9663$ K = 0.9663

Table 134

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y12 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fd	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-5	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}$.5	1.00	-1.50	-4	-4.00	16.00	-64.00	256.00	625.00
$\bar{1}$ - 0	$\bar{0}$.5	2.39	-1.19	-3	-7.17	21.51	-64.53	193.59	611.84
0 - 1	0.5	5.06	2.53	-2	-10.12	20.24	-40.48	80.96	409.86
1 - 2	1.5	17.80	26.70	-1	-17.80	17.80	-17.80	17.80	284.80
2 - 3	$\bar{X}_o$=2.5	24.88	62.20	0	0.00	0.00	0.00	0.00	24.88
3 - 4	3.5	19.87	69.54	1	19.87	19.87	19.87	19.87	0.00
4 - 5	4.5	8.43	37.93	2	16.86	33.72	67.44	134.88	8.43
5 - 6	5.5	5.00	27.50	3	15.00	45.00	135.00	405.00	80.00
6 - 7	6.5	12.00	78.00	4	48.00	192.00	768.00	3072.00	972.00
7 - 8	7.5	1.50	11.25	5	7.50	37.50	187.50	937.50	384.00
8 - 9	8.5	2.07	17.60	6	12.42	74.52	447.12	2682.72	1293.75
9		0.00	0.00	7	0.00	0.00	0.00	0.00	0.00
Total	Σ	100	330.56		80.56	478.16	1438.12	7800.32	4694.56
moments around the arbitrary origin					n_1 = 0.806	n_2 = 4.782	n_3 = 14.381	n_4 = 78.00	

m = midpoint of each class f = frequency $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean M_ϕ = logarithmetic mean c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness σ_ϕ = standard deviation K = kurtosis $\overline{X}_o = 2.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 3.31 \qquad m_1 = X = \overline{X}_o + cn_1 = 3.306$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.1324 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 3.8652$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 49.0083 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.0328$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.4601 \qquad SK = \frac{\sqrt{b_1}}{2} = 0.23$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 2.8701 \qquad K = b_2 - 3 = -0.1299$$

Summary: $\overline{X} = 3.306$ $M_\phi = 0.84$ $\sigma_\phi = 1.3249$ $SK = 1.5691$

$\sqrt{b_1} = 0.4601$ $b_2 = 2.8701$ $K = -0.1299$

Table 135

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y13 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-7	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-6	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	2.07	-1.03	-5	-10.35	51.75	-258.75	1293.75	2682.72
0 - 1	0.5	5.00	2.50	-4	-20.00	80.00	-320.00	1280.00	3125.00
1 - 2	1.5	8.43	12.64	-3	-25.29	75.87	-227.61	682.83	2158.08
2 - 3	2.5	12.00	30.00	-2	-24.00	48.00	-96.00	192.00	972.00
3 - 4	3.5	19.87	69.54	-1	-19.87	19.87	-19.87	19.87	317.92
4 - 5	$\bar{X}_o$=4.5	24.88	111.96	0	0.00	0.00	0.00	0.00	24.88
5 - 6	5.5	17.80	79.90	1	17.80	17.80	17.80	17.80	0.00
6 - 7	6.5	5.06	32.89	2	10.12	20.24	40.48	80.96	5.06
7 - 8	7.5	2.39	17.92	3	7.17	21.51	64.53	193.59	38.24
8 - 9	8.5	1.50	12.75	4	6.00	24.00	96.00	384.00	121.50
9		1.00	9.50	5	5.00	25.00	125.00	625.00	256.00
Total	Σ	100	296.57		-53.42	384.04	-578.42	4769.80	12383.40
moments around the arbitrary origin					n_1 = -0.53	n_2 = 3.84	n_3 = -5.78	n_4 = 47.70	

m = midpoint of each class   f = frequency $\overline{X}$ = arithmetic mean

X_ϕ = assumed mean M_ϕ = logarithmetic mean   c = class intervals

$n_1 = \frac{\Sigma fd}{\Sigma f}$ $n_2 = \frac{\Sigma fd^2}{\Sigma f}$ $n_3 = \frac{\Sigma fd^3}{\Sigma f}$ $n_4 = \frac{\Sigma fd^4}{\Sigma f}$

SK = skewness σ_ϕ = standard deviation   K = kurtosis $\overline{X}_o = 4.5$

$M_\phi = \frac{\Sigma fm}{\Sigma f} = 2.97$

$m_1 = X = X_o \text{ A } cn_1 = 3.97$

$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 3.56$

$m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = 0.04$

$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 41.68$

$\sigma_\phi = \sqrt{\sigma^2} = 1.88$

$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = 0.006$

$SK = \frac{\sqrt{b_1}}{2} = 0.003$

$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.345$

$K = b_2 - 3 = 0.345$

Summary: $\overline{X} = 3.97$ $M_\phi = 2.97$ $\sigma_\phi = 1.88$ $SK = 0.003$

$\sqrt{b_1} = 0.006$ $b_2 = 3.345$ $K = 0.345$

Table 136

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y14 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-8	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-7	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	0.98	-0.49	-6	-5.88	35.28	-211.68	1270.08	2352.98
0 - 1	0.5	1.98	0.99	-5	-9.90	49.50	-247.50	1237.50	2566.08
1 - 2	1.5	2.18	3.27	-4	-8.72	34.88	-139.52	558.08	1362.50
2 - 3	2.5	3.80	9.50	-3	-11.40	34.20	-102.60	307.80	972.80
3 - 4	3.5	4.02	14.07	-2	-8.04	16.08	-32.16	64.32	325.62
4 - 5	4.5	13.76	61.92	-1	-13.76	13.76	-13.76	13.76	22.16
5 - 6	$\bar{X}_o$=5.5	21.41	117.75	0	0.00	0.00	0.00	0.00	21.41
6 - 7	6.5	19.96	129.74	1	19.96	19.96	19.96	19.96	0.00
7 - 8	7.5	17.45	130.87	2	34.90	69.80	139.60	279.20	17.45
8 - 9	8.5	9.85	83.72	3	29.55	88.65	265.95	797.85	157.60
9		4.61	43.79	4	18.44	73.76	295.04	1180.16	373.41
Total	Σ	100	595.13		45.15	435.87	-203.97	5728.71	8370.01
moments around the arbitrary origin					n_1 = 0.45	n_2 = 4.36	n_3 = -2.04	n_4 = 57.29	

m = midpoint of each class $\quad$ f = frequency $\quad$ $\overline{X}$ = arithmetic mean

$\overline{X}_\phi$ = assumed mean $\quad$ M_ϕ = logarithmetic mean $\quad$ c = class intervals

$$n_1 = \frac{\Sigma\ fd}{\Sigma\ f} \qquad n_2 = \frac{\Sigma\ fd^2}{\Sigma\ f} \qquad n_3 = \frac{\Sigma\ fd^3}{\Sigma\ f} \qquad n_4 = \frac{\Sigma\ fd^4}{\Sigma\ f}$$

SK = skewness $\quad$ σ_ϕ = standard deviation $\quad$ K = kurtosis $\quad$ $\overline{X}_o = 5.5$

$$M_\phi = \frac{\Sigma\ fm}{\Sigma\ f} = 5.95 \qquad m_1 = X = X_o + cn_1 = 5.95$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 4.16 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -7.74$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 66.03 \qquad \sigma_\phi = \sqrt{\sigma^2} = 2.03$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.925 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.462$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 3.888 \qquad K = b_2 - 3 = 0.888$$

Summary: $\overline{X} = 5.95$ $\quad$ $M_\phi = 5.95$ $\quad$ $\sigma_\phi = 2.03$ $\quad$ SK = -0.462

$\sqrt{b_1} = -0.925$ $\quad$ $b_2 = 3.888$ $\quad$ K = 0.888

Table 137

Computation of Statistics from the first moments of a frequency distribution of a Sample No. Y15 from fan FY-11 east of Jebāl Umm ad Dabāh.

class limits ϕ	m	f	fm	d	fd	fd^2	fd^3	fd^4	$f(d-1)^4$
$\bar{2}$		0.00	0.00	-8	0.00	0.00	0.00	0.00	0.00
$\bar{2}$ - $\bar{1}$	$\bar{1}.5$	0.00	0.00	-7	0.00	0.00	0.00	0.00	0.00
$\bar{1}$ - 0	$\bar{0}.5$	0.50	-0.25	-6	-3.00	18.00	-108.00	648.00	1200.50
0 - 1	0.5	1.00	0.50	-5	-5.00	25.00	-125.00	625.00	1296.00
1 - 2	1.5	1.50	2.25	-4	-6.00	24.00	-96.00	384.00	937.50
2 - 3	2.5	2.5	6.25	-3	-7.50	22.50	-67.50	202.50	640.00
3 - 4	3.5	4.62	16.17	-2	-9.24	18.48	-36.96	73.92	374.22
4 - 5	4.5	23.78	107.01	-1	-23.78	23.78	-23.78	23.78	380.48
5 - 6	$\bar{X}_o=5.5$	33.73	185.51	0	0.00	0.00	0.00	0.00	33.73
6 - 7	6.5	22.57	146.70	1	22.57	22.57	22.57	22.57	0.00
7 - 8	7.5	6.78	50.85	2	13.56	27.12	54.24	108.48	6.78
8 - 9	8.5	2.64	22.44	3	7.92	23.76	71.28	213.84	42.24
9	9.5	0.38	7.88	4	3.32	13.26	53.12	212.48	67.23
Total	Σ	100	545.31		-7.15	218.47	-256.03	2514.57	4978.68
moments around the arbitrary origin					n_1 = -0.07	n_2 = 2.18	n_3 = -2.56	n_4 = 25.15	

m = midpoint of each class $\quad f$ = frequency $\quad \bar{X}$ = arithmetic mean

X_ϕ = assumed mean $\quad M_\phi$ = logarithmetic mean $\quad c$ = class intervals

$$n_1 = \frac{\Sigma\, fd}{\Sigma\, f} \qquad n_2 = \frac{\Sigma\, fd^2}{\Sigma\, f} \qquad n_3 = \frac{\Sigma\, fd^3}{\Sigma\, f} \qquad n_4 = \frac{\Sigma\, fd^4}{\Sigma\, f}$$

SK = skewness $\quad \sigma_\phi$ = standard deviation $\quad$ K = kurtosis $\quad \bar{X}_o = 0.5$

$$M_\phi = \frac{\Sigma\, fm}{\Sigma\, f} = 5.45 \qquad m_1 = X = X_o + cn_1 = 5.43$$

$$m_2 = \sigma^2 = c^2(n_2 - n_1^2) = 2.18 \qquad m_3 = c^3(n_3 - 3n_2n_1 + 2n_1^3) = -2.11$$

$$m_4 = c^4(n_4 - 4n_3n_1 + 6n_1^2n_2 - 3n_1^4) = 24.47 \qquad \sigma_\phi = \sqrt{\sigma^2} = 1.47$$

$$\sqrt{b_1} = \frac{m_3}{\sigma_\phi^3} = -0.664 \qquad SK = \frac{\sqrt{b_1}}{2} = -0.332$$

$$b_2 = \frac{m_4}{\sigma_\phi^4} = 5.243 \qquad K = b_2 - 3 = 2.243$$

Summary: $\bar{X} = 5.43$ $\quad M_\phi = 5.45$ $\quad \sigma_\phi = 1.47$ $\quad SK = -0.332$

$\sqrt{b_1} = -0.664$ $\quad b_2 = 5.243$ $\quad K = 2.243$

Table 138

Two way analysis of variance for the sample means in relation to distance and depth on fan FXI

Distance / Depth	200 m. A	700 m. B	1200 m. C	1700 m. D	2200 m. E	B_j
1 surface	0.976	0.095	0.274	1.943	2.753	$\overline{X}1$=1.2082
2 2 m.	0.233	1.977	1.782	2.570	2.554	$\overline{X}2$=1.8232
3 4 m.	0.453	2.567	2.305	2.455	2.338	$\overline{X}3$=2.0236
a_i	$\overline{X}A$=0.5540	$\overline{X}B$=1.5463	$\overline{X}C$=1.7536	$\overline{X}D$=2.3226	$\overline{X}E$=2.5483	ΣX=1.6850

TSS = 13.6692
RMS = 0.9027
CMS = 1.8779
EMS = 0.5440
$SE(d_r)$ = 0.6021

RSS = 1.8054
CSS = 7.5116
ESS = 4.3522
F_r = 1.6593
$SE(d_c)$ = 0.4664

n - 1 = 2
m - 1 = 4
(n-1)(m-1) = 8
F_c = 3.4520
(2,8) = 4.46 Fo5,2,8
(4,8) = 3.84 Fo5,4,8

Table 139

Two way analysis of variance for the sample standard deviation in relation to distance and depth on fan FXI

Distance / Depth	200 m. A	700 m. B	1200 m. C	1700 m. D	2200 m. E	B_j
1 surface	1.7738	1.9271	1.8963	2.3788	1.4460	$\overline{X}1$=1.8844
2 2 m.	1.8403	1.4941	2.0602	1.9811	1.4916	$\overline{X}2$=1.7734
3 4 m.	1.8678	1.4080	2.0988	1.6783	1.4353	$\overline{X}3$=1.6976
a_i	$\overline{X}A$=1.8273	$\overline{X}B$=1.6097	$\overline{X}C$=2.0184	$\overline{X}D$=2.0127	$\overline{X}E$=1.4576	ΣX=1.7851

TSS = 1.1703
RMS = 0.0450
CMS = 0.1849
EMS = 0.0425
$SE(d_r)$ = 0.1682

RSS = 0.0900
CSS = 0.7398
ESS = 0.3405
F_r = 1.0588
$SE(d_c)$ = 0.1303

n - 1 = 2
m - 1 = 4
(n-1)(m-1) = 8
F_c = 4.3505
(2,8) = 4.46 Fo5,2,8
(4,8) = 3.84 Fo5,2,8

Table 140

Two way analysis of variance for the sample means in relation to distance and depth on fan FYII

Distance / Depth	200 m. A	700 m. B	1200 m. C	1700 m. D	2200 m. E	B_j
1 surface	-0.005	1.548	2.385	2.595	3.970	$\overline{X}1$=2.0986
2 2 m.	0.632	1.973	2.957	3.250	5.950	$\overline{X}2$=9524
3 4 m.	0.840	2.247	3.124	3.306	5.430	$\overline{X}3$=2.9894
a_i	$\overline{X}A$=0.4890	$\overline{X}B$=1.9226	$\overline{X}C$=2.8220	$\overline{X}D$=3.0503	$\overline{X}E$=5.1166	ΣX=2.6801

TSS = 37.7634
RMS = 1.2705
CMS = 8.6018
EMS = 0.1018
SE(d_r) = 0.2603

RSS = 2.5411
CSS = 34.4074
ESS = 0.8149
F_r = 12.4803
SE(d_c) = 0.2017

n - 1 = 2
m - 1 = 4
(n-1)(m-1) = 8
F_c = 84.4970
(2,8) = 8.65 (4,8) = 7.01
Fo1,2,8 Fo1 ,4,8

Table 141

Two way analysis of variance for the sample standard deviation in relation to distance and depth on fan FYII

Distance / Depth	200 m. A	700 m. B	1200 m. C	1700 m. D	2200 m. E	B_j
1 surface	2.060	1.0225	2.7283	1.576	1.880	$\overline{X}1$=1.8533
2 2 m.	2.0382	0.8799	2.1794	2.4741	2.030	$\overline{X}2$=1.9203
3 4 m.	1.3249	1.1251	2.8181	2.0328	1.470	$\overline{X}3$=1.7541
a_i	$\overline{X}A$=1.8077	$\overline{X}B$=1.0091	$\overline{X}C$=2.5752	$\overline{X}D$=2.0276	$\overline{X}E$=1.7933	ΣX=1.8426

TSS = 4.9986
RMS = 0.0352
CMS = 0.9521
EMS = 0.1399
SE(d_r) = 0.3052

RSS = 0.0704
CSS = 3.8084
ESS = 1.1198
F_r = 0.2516
SE(d_c) = 0.2364

n - 1 = 2
m - 1 = 4
(n-1)(m-1) = 8
F_c = 6.8055
(2,8) = 4.46 (4,8) = 5.05
Fo5,2,8 Fo25,4,8

Table 142

Summary of the analysis of variance (two way classification without replicates) of the means and standard deviation of samples from fan FXI

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	$F_{0.10}$	$F_{0.05}$	$F_{0.025}$
d=3	Between depths	d-1=2	1.8054	0.9027	1.6593	3.11	4.46	6.06
D=5	Among distances	D-1=4	7.5116	1.8779	3.4520*	2.81	3.84	5.05
	Error	(d-1)(D-1) = 8	4.3522	0.5440				
dD=15		dD-1 = 14	13.6692					
	SE (d_r) = 0.6021				SE (d_c) = 0.4664			

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	$F_{0.10}$	$F_{0.05}$	$F_{0.025}$
d=3	Between depths	d-1=2	0.0900	0.0450	1.0588	3.11	4.46	6.06
D=5	Among distances	D-1=4	0.7398	0.1849	4.3505*	2.81	3.84	5.05
	Error	(d-1)(D-1) = 8	0.3705	0.0425				
dD=15		dD-1 = 14	1.1703					
	SE (d_r) = 0.1682				SE (d_c) = 0.1303			

Table 143

Summary of the analysis of variance (two way classification without replicates) of the means and the standard deviations of samples from fan FYII

$\bar{X}_\phi$

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	$F_{0.05}$	$F_{0.025}$	$F_{0.01}$
d=3	Between depths	d-1=2	2.5411	1.2705	12.4803***	4.46	6.06	8.65
D=5	Among distances	D-1=4	34.4074	8.6018	84.4970***	3.84	5.05	7.01
	Error	(d-1)(D-1) = 8	0.8149	0.1018				
dD=15		dD-1 = 14	37.7634					

SE (d_r) = 0.2603 SE (d_c) = 0.2017

σ_ϕ

No. of items	Source of variation	d.f.	Sum of squares	Mean square	Variance ratio F	$F_{0.10}$	$F_{0.05}$	$F_{0.025}$
d=3	Between depths	d-1=2	0.0704	0.0352	0.2516	3.11	4.46	6.06
						$F_{0.05}$	$F_{0.025}$	$F_{0.01}$
D=5	Among distances	D-1=4	3.8087	0.9521	6.8055**	3.84	5.05	7.01
	Error	(d-1)(D-1) = 8	1.1198	0.1399				
dD=15		dD-1 = 14	4.9986					

SE (d_r) = 0.3052 SE (d_c) = 0.2364

Table 144

Comparison of hillslopes of the catchment areas for the alluvial fans East of Jebāl umm ad Dabāh

Catchment area	No. of slopes	Average slope	Range	Standard deviation
FXI - A	30	30°32'	15°-35°15'	7°41'
FYII - B	32	24°25'	10°-25°20'	5°36'

Table 145

Comparison of slopes on alluvial fans east of Jebāl umm ad Dabāh

Alluvial fan area	No. of slopes	Average	Range	Standard deviation
FXI	24	2°31'	29'-4°	1°
FYII	20	2°42'	45'-2°59'	53'

Table 146

Average percentage of alluvial fan areas
East of Jebāl umm ad Dabāh

	FXI	FXYII
mountains	81.4	79.9
fan	18.6	20.1

Correlation data

alluvial fan slope and mountain slope	No. of values	correlation	significant level (P)
FXI	54	-0.533	0.001 P
FXYII	52	-0.480	0.001
alluvial fan length and alluvial fan slope			
FXI	29	0.231	0.1 P 0.05
FYII	25	0.240	0.1 P 0.05
mean size and alluvial fan length			
FXI	20	0.999	0.001 P
FYII	20	0.979	0.001 P
mean size and fan depth			
FXI	18	0.875	0.001 P
FYII	18	0.890	0.001 P

Table 147

Percentage of the source areas and the depositional areas of the alluvial fans east of Jebāl Umm ad Dabāh

SOURCE AREA (A)							DEPOSITION AREA (B)						
a	% fca	% A	% AI	% AI of A	A		b	% fa	% B	% BI	% BI of B	B	
a1	56.0	0.8	78.0	38.2	A I	% A (I,II,III) = 33.1	b1	44.0	3.0	22.0	50.0	B I	% B (I,II,III) = 9.0
a2	61.0	1.8					b2	39.0	5.2				
a3	66.0	1.9					b3	34.0	4.5				
a4	55.8	1.9					b4	44.2	7.1				
a5	64.5	3.2					b5	35.5	8.2				
a6	73.0	4.4					b6	27.0	7.5				
a	% fca	% A	% AII	% AII of A			b	% fa	% B	% BII	% BII of B		
a7	70,0	6.8	81.5	14.2	A II	% A of AB = 82.2	b7	30.0	13.4	18.5	20.9	B II	% B of AB = 17.8
a8	73.2	4.0					b8	26.8	6.7				
a	% fca	% A	% AIII	% AIII of A			b	% fa	% B	% BIII	% BIII of B		
a9	69.9	9.4	76.9	14.5	A III		b9	30.1	18.7	23.1	20.1	B III	

A = Total catchment area

AB = Total area of deposition and sources

a = individual catchments

fca = fan catchment area

AI = catchment area of bahada I

AII = catchment area of bahada II

AIII = catchment area of bahada III

B = Total bahada segment

b = individual fans

fa = fan area

BI = Bahada area I

BII = bahada area II

BIII = bahada area III

HISTOGRAM 3

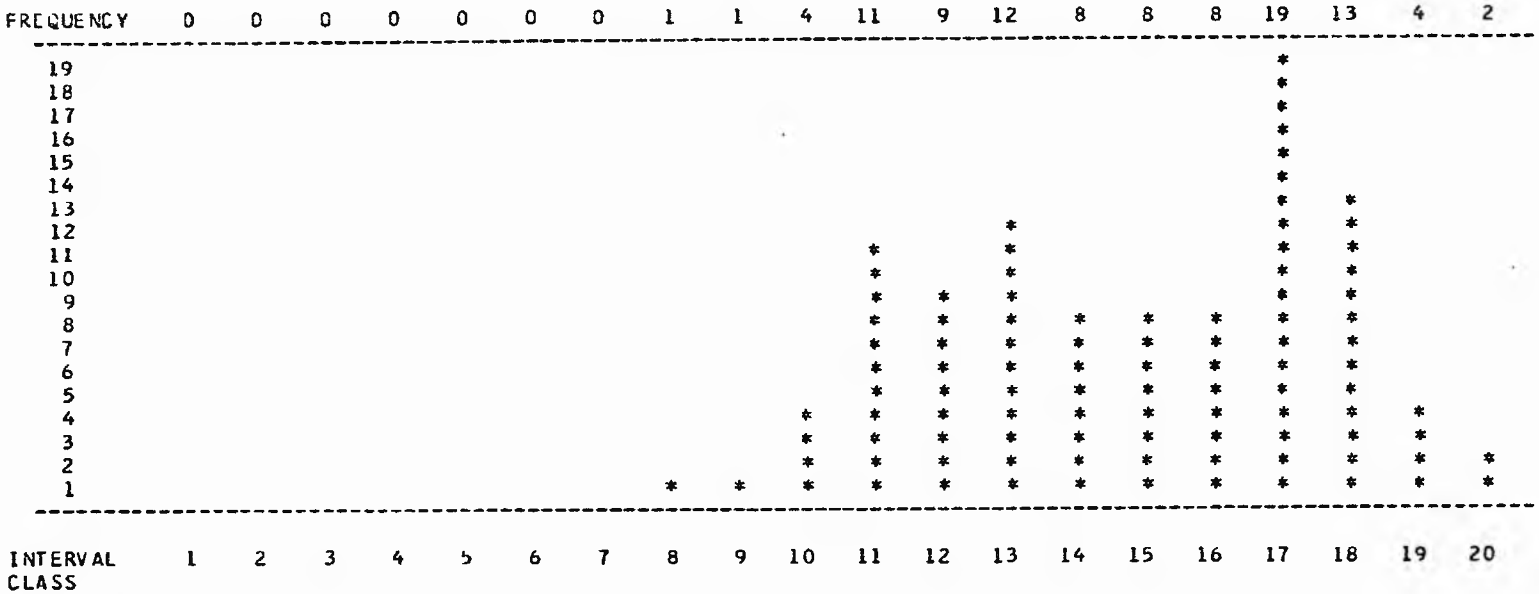


Fig. 78. Histogram for sphericity of pebbles from site one of pediment A,

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.709	0.020	0.140	-0.189	1.877

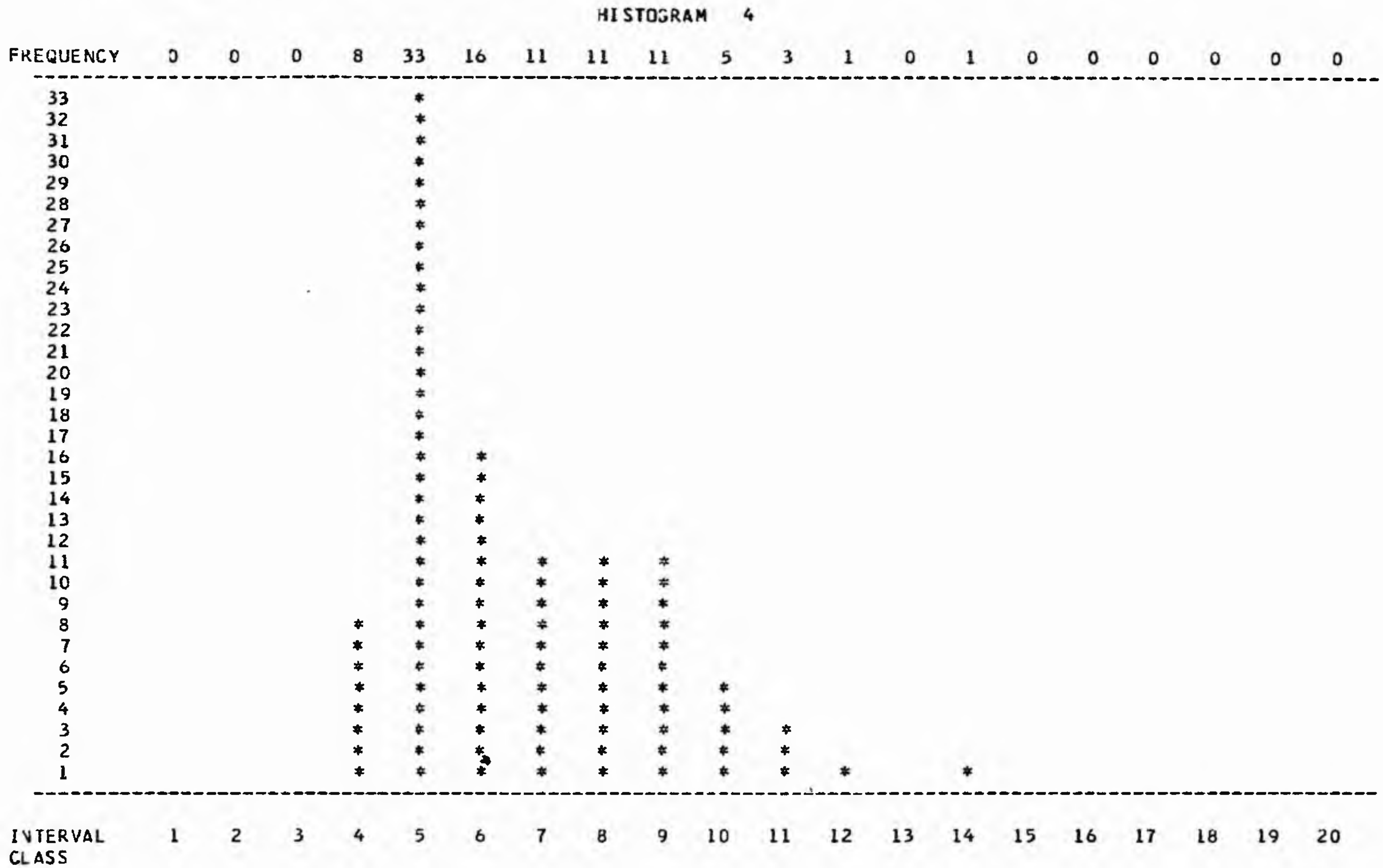


Fig. 79. Histogram for flatness of pebbles from site one of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.843	0.386	0.621	1.005	3.686

```
                                      HISTOGRAM   5

FREQUENCY    0   0  10  21  27  18   9   4   4   4   2   0   0   0   1   0   0   0   0   0
-----------------------------------------------------------------------------------------
        27                   *
        26                   *
        25                   *
        24                   *
        23                   *
        22                   *
        21               *   *
        20               *   *
        19               *   *
        18               *   *   *
        17               *   *   *
        16               *   *   *
        15               *   *   *
        14               *   *   *
        13               *   *   *
        12               *   *   *
        11               *   *   *
        10           *   *   *   *
         9           *   *   *   *   *
         8           *   *   *   *   *
         7           *   *   *   *   *
         6           *   *   *   *   *
         5           *   *   *   *   *
         4           *   *   *   *   *   *   *   *
         3           *   *   *   *   *   *   *   *
         2           *   *   *   *   *   *   *   *   *
         1           *   *   *   *   *   *   *   *   *               *
-----------------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 80. Histogram for roundness of pebbles from site one of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
256.787	11267.484	106.148	1.463	6.038

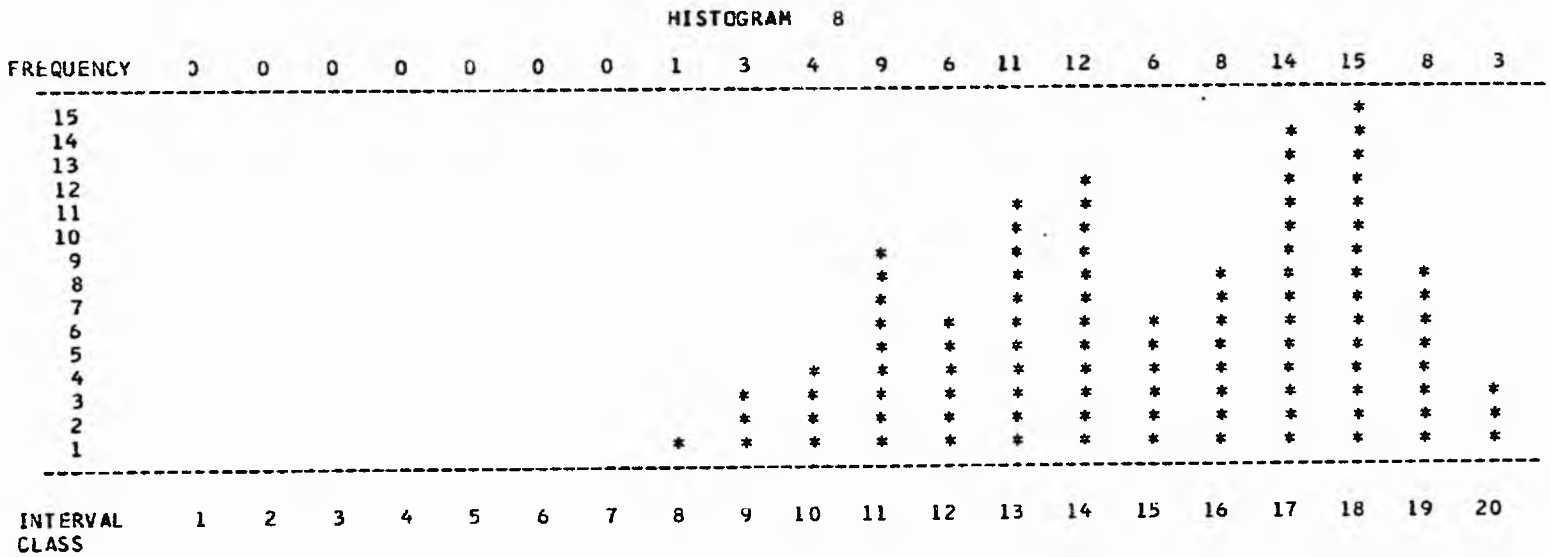


Fig. 81. Histogram for sphericity of pebbles from site two of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.722	0.023	0.152	-0.297	1.960

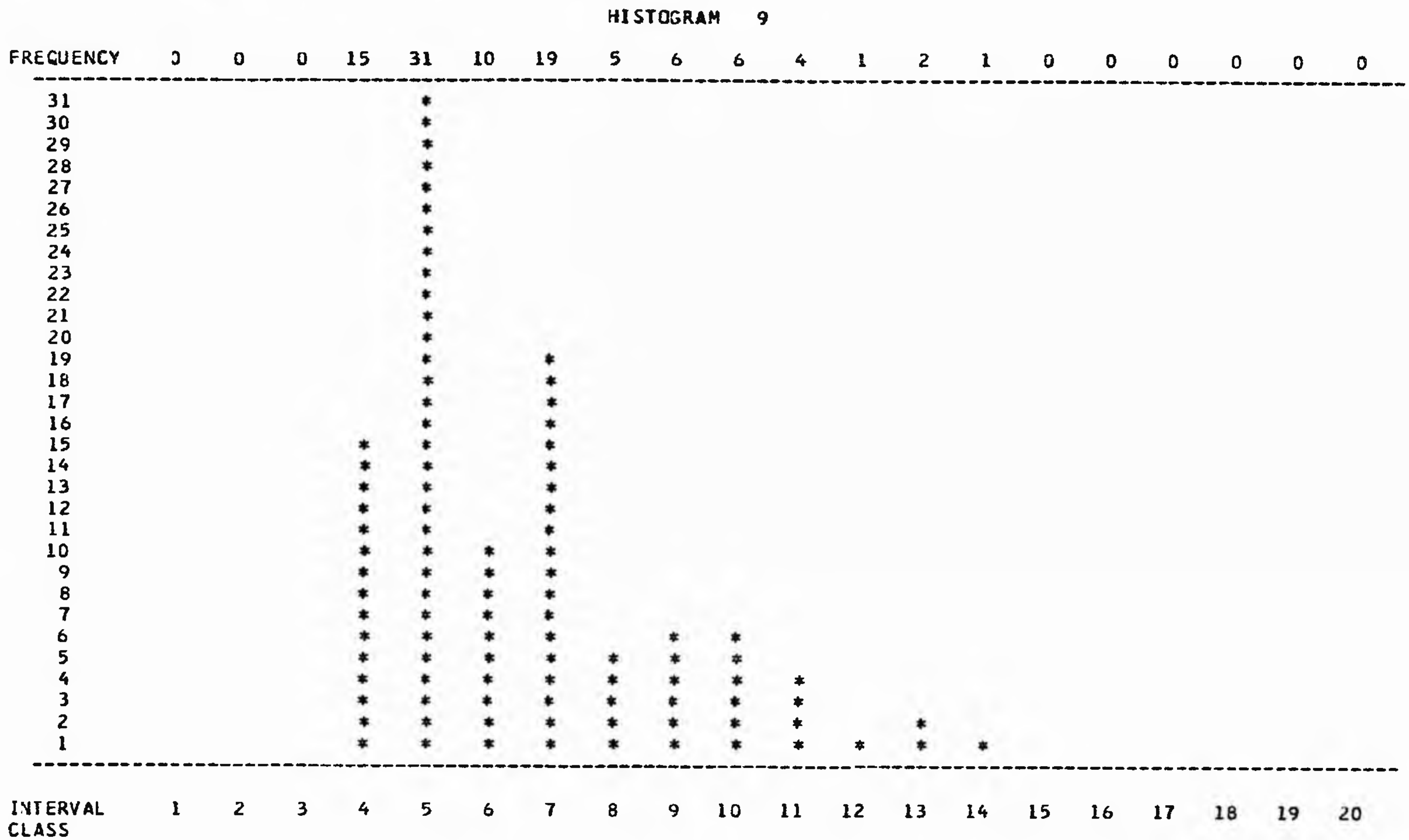


Fig. 82. Histogram for flatness of pebbles from site two of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.825	0.485	0.696	1.174	3.823

```
                                   HISTOGRAM 10

FREQUENCY      1   0  11  20  15  18  16   7   5   4   2   1   0   0   0   0   0   0   0   0
        ------------------------------------------------------------------------------------
         20                *
         19                *
         18                *       *
         17                *       *
         16                *       *   *
         15                *   *   *   *
         14                *   *   *   *
         13                *   *   *   *
         12                *   *   *   *
         11            *   *   *   *   *
         10            *   *   *   *   *
          9            *   *   *   *   *
          8            *   *   *   *   *
          7            *   *   *   *   *   *
          6            *   *   *   *   *   *
          5            *   *   *   *   *   *   *
          4            *   *   *   *   *   *   *   *
          3            *   *   *   *   *   *   *   *
          2            *   *   *   *   *   *   *   *   *
          1    *       *   *   *   *   *   *   *   *   *   *
        ------------------------------------------------------------------------------------

INTERVAL       1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 83. Histogram for roundness of pebbles from site two of pediment A.

```
MOMENT MEASURES

     MEAN       VARIANCE        STAN. DEV.       SKEWNESS       KURTOSIS
    263.135     11382.867        106.691          0.634          2.991
```

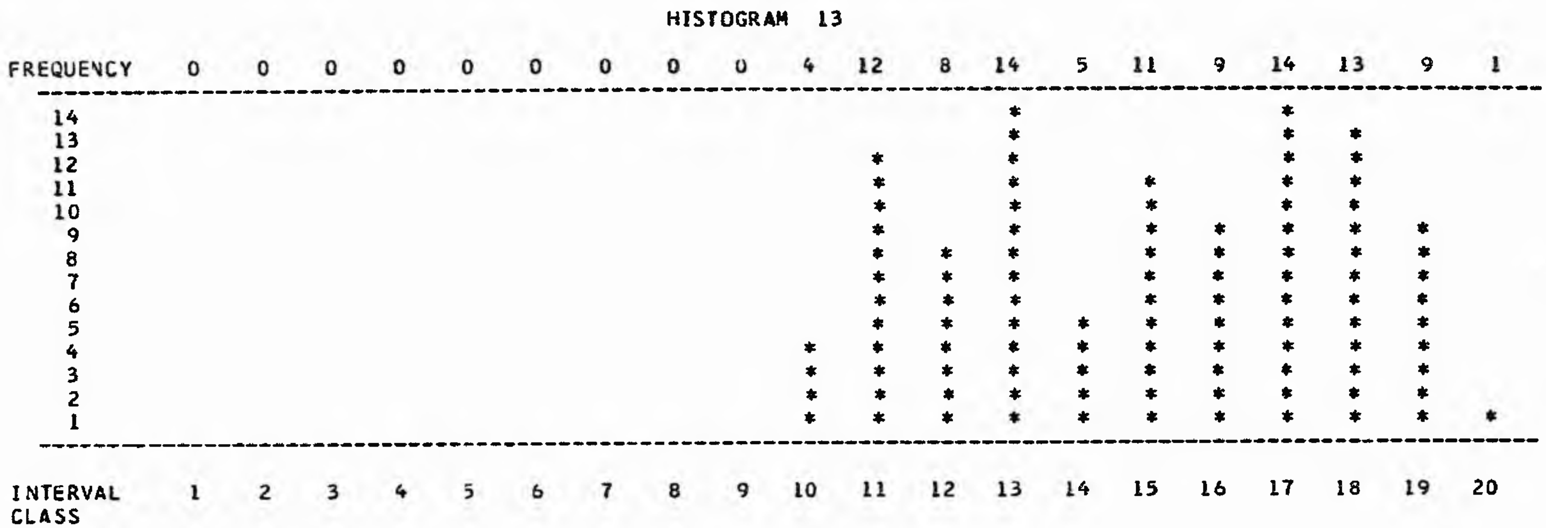


Fig. 84. Histogram for sphericity of pebbles from site three of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.720	0.020	0.141	-0.074	1.710

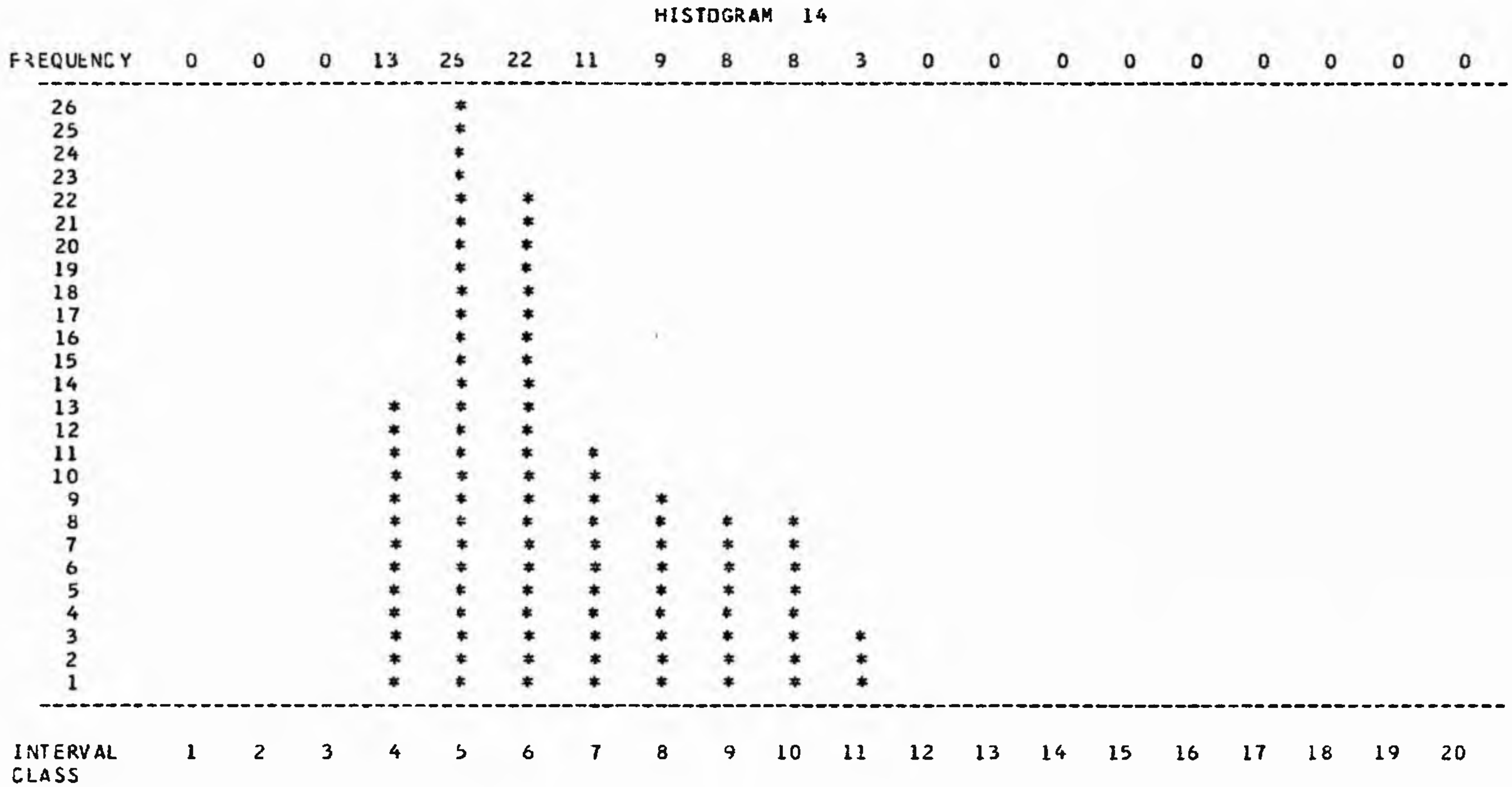


Fig. 85. Histogram for flatness of pebbles from site three of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.789	0.329	0.574	0.650	2.231

HISTOGRAM 15

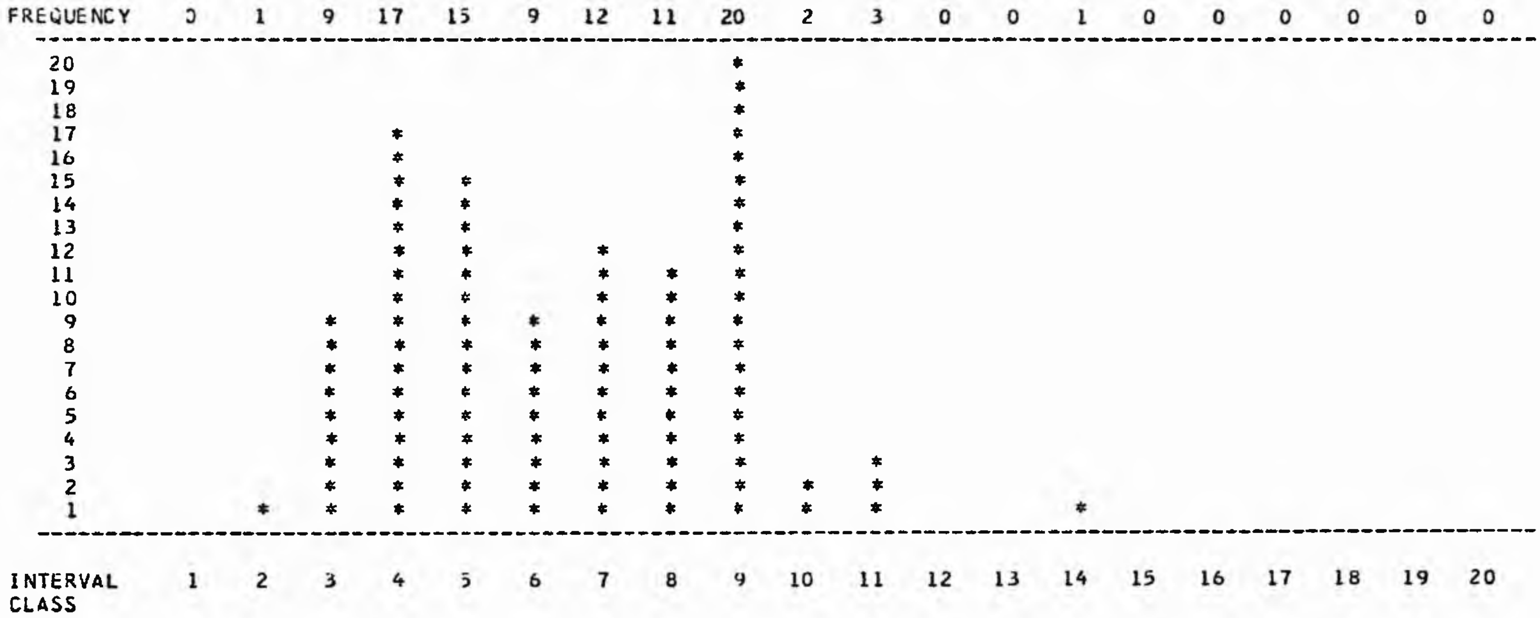


Fig. 86. Histogram for roundness of pebbles from site three of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
293.554	14170.109	119.038	0.402	2.496

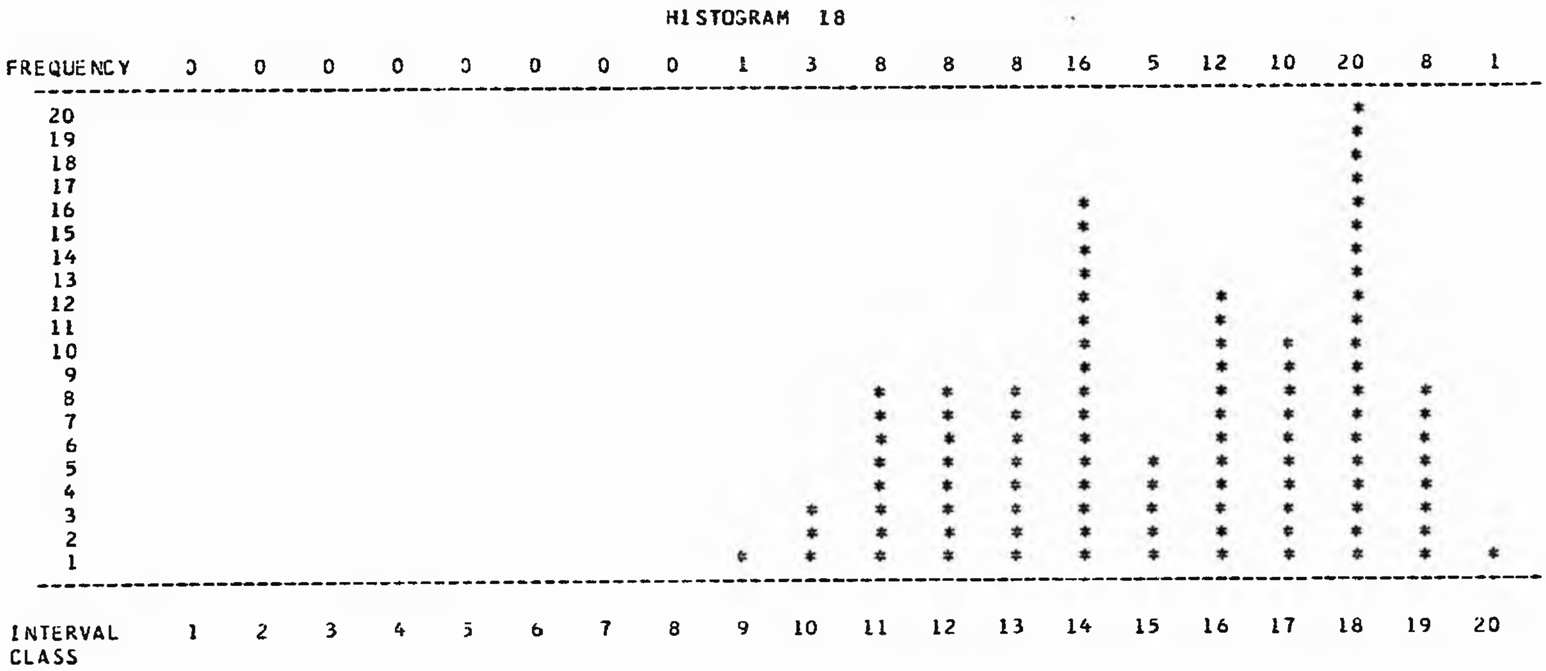


Fig. 87. Histogram for sphericity of pebbles from site four of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.736	0.019	0.137	-0.261	1.957

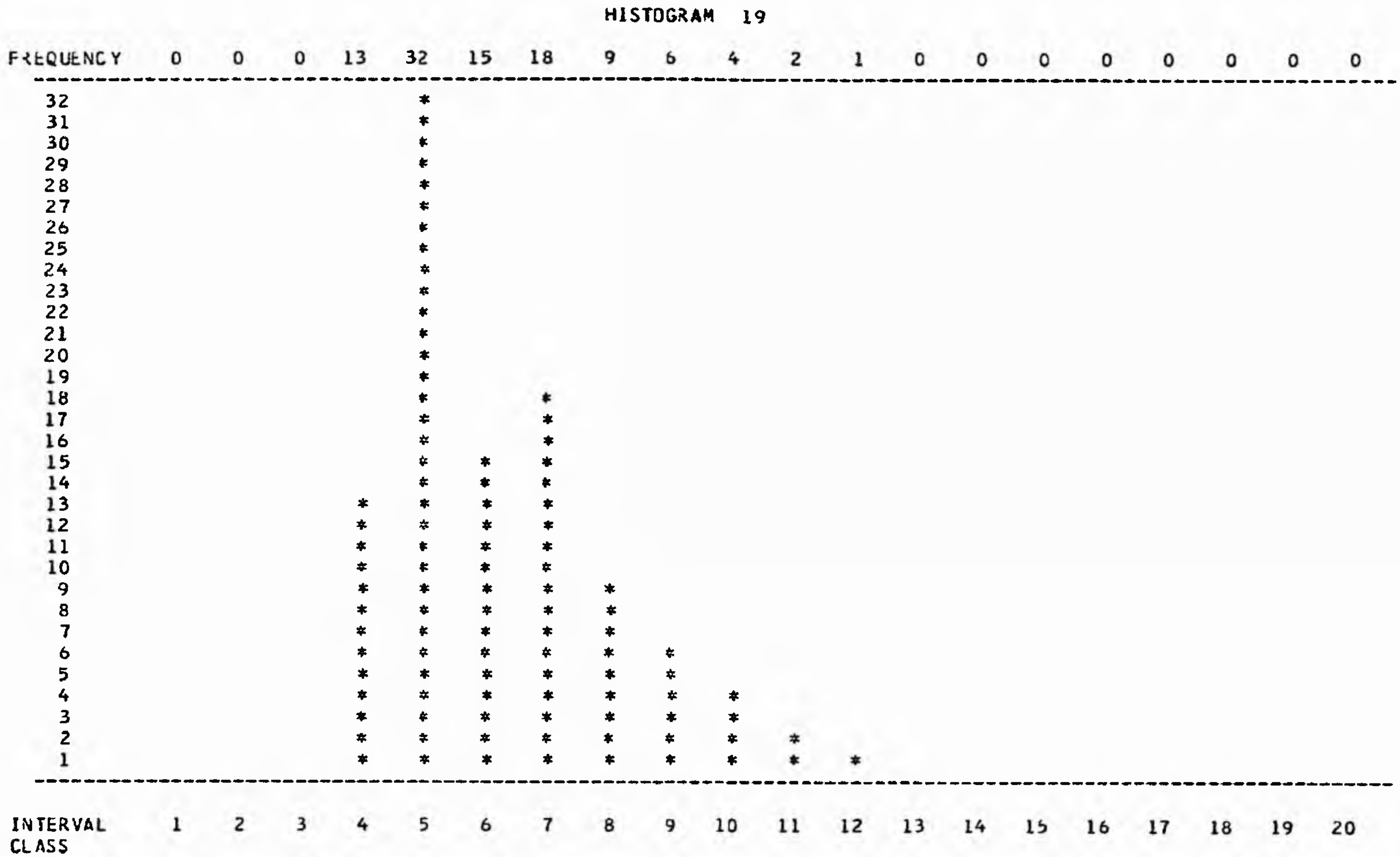


Fig. 88. Histogram for flatness of pebbles from site four of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.725	0.311	0.558	1.027	3.470

```
                                         HISTOGRAM  20

FREQUENCY   0   0   7   8  17   8  10   8   9   7   8   5   8   3   1   1   0   0   0   0
----------------------------------------------------------------------------------------
   17                       *
   16                       *
   15                       *
   14                       *
   13                       *
   12                       *
   11                       *
   10                       *       *
    9                       *       *       *
    8                   *   *   *   *   *   *       *       *
    7               *   *   *   *   *   *   *   *   *       *
    6               *   *   *   *   *   *   *   *   *       *
    5               *   *   *   *   *   *   *   *   *   *   *
    4               *   *   *   *   *   *   *   *   *   *   *
    3               *   *   *   *   *   *   *   *   *   *   *   *
    2               *   *   *   *   *   *   *   *   *   *   *   *
    1               *   *   *   *   *   *   *   *   *   *   *   *   *   *
----------------------------------------------------------------------------------------

INTERVAL    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 89. Histogram for roundness of pebbles from site four of pediment A.

```
MOMENT  MEASURES

      MEAN        VARIANCE        STAN. DEV.       SKEWNESS        KURTOSIS
    368.432      27576.613         166.062          0.385           2.056
```

HISTOGRAM 23

```
FREQUENCY    0   0   0   0   0   0   1   3   4   7   7   6  11  10  10   6  15   7   9   4
------------------------------------------------------------------------------------------
    15                                                                     *
    14                                                                     *
    13                                                                     *
    12                                                                     *
    11                                                     *               *
    10                                                     *   *   *       *
     9                                                     *   *   *       *       *
     8                                                     *   *   *       *       *
     7                                         *   *       *   *   *       *   *   *
     6                                         *   *   *   *   *   *   *   *   *   *
     5                                         *   *   *   *   *   *   *   *   *   *
     4                                     *   *   *   *   *   *   *   *   *   *   *   *
     3                                 *   *   *   *   *   *   *   *   *   *   *   *   *
     2                                 *   *   *   *   *   *   *   *   *   *   *   *   *
     1                             *   *   *   *   *   *   *   *   *   *   *   *   *   *
------------------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 90. Histogram for sphericity of pebbles from site five of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.698	0.027	0.164	-0.240	2.044

HISTOGRAM 24

INTERVAL CLASS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
FREQUENCY	0	0	0	15	21	20	11	8	6	6	4	3	0	3	1	1	0	1	0	0

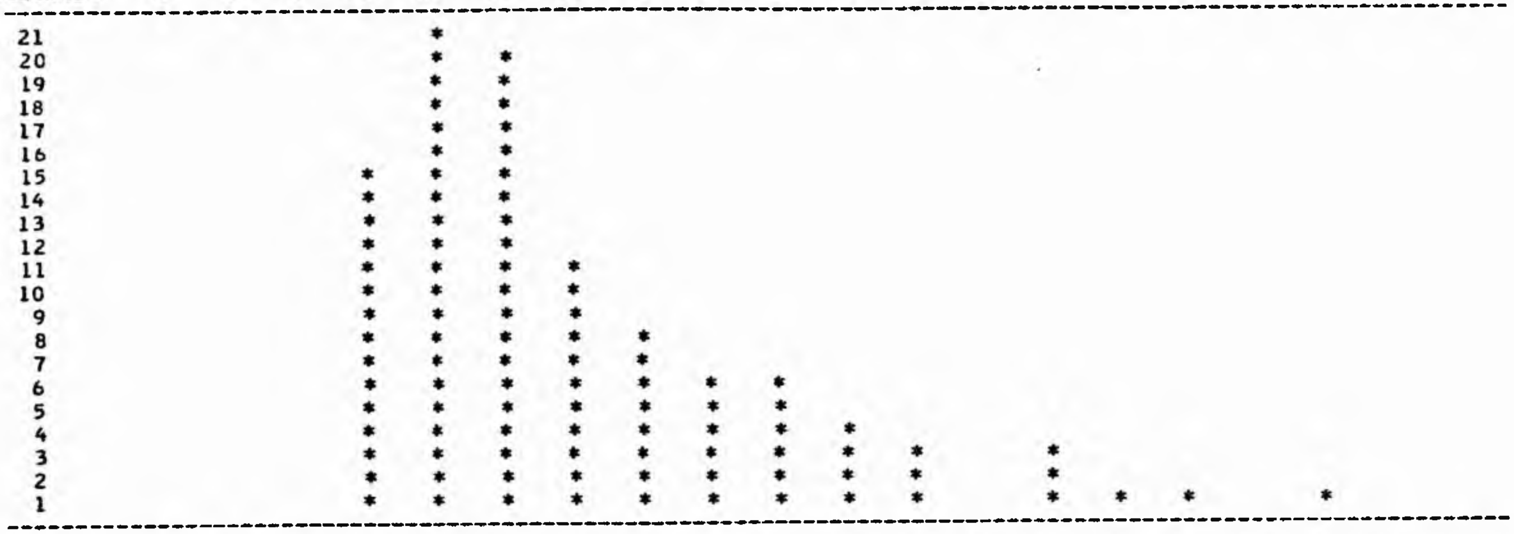


Fig. 91. Histogram for flatness of pebbles from site five of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.978	0.769	0.877	1.379	4.525

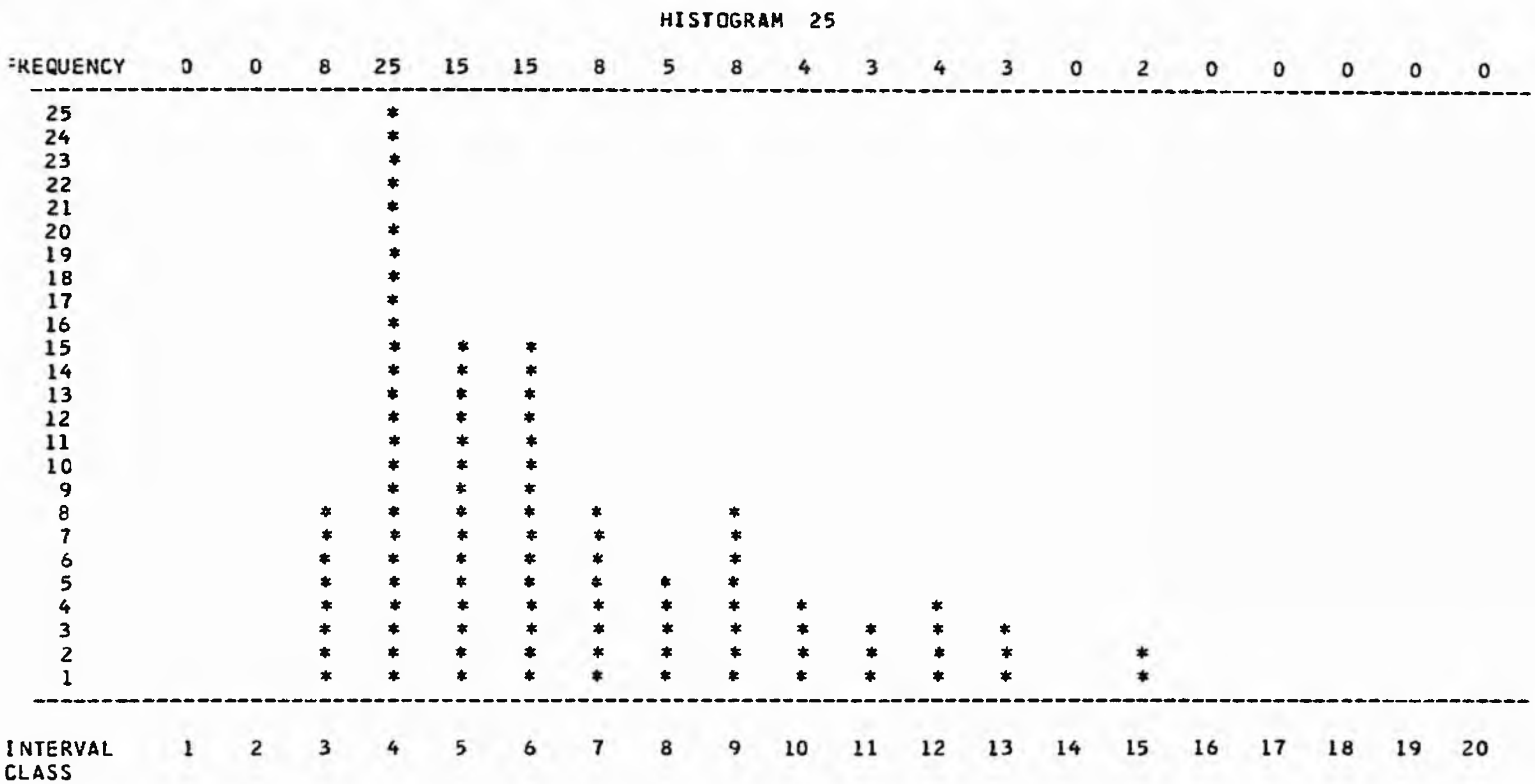


Fig. 92. Histogram for roundness of pebbles from site five of pediment A.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
294.506	22074.160	148.574	1.021	3.278

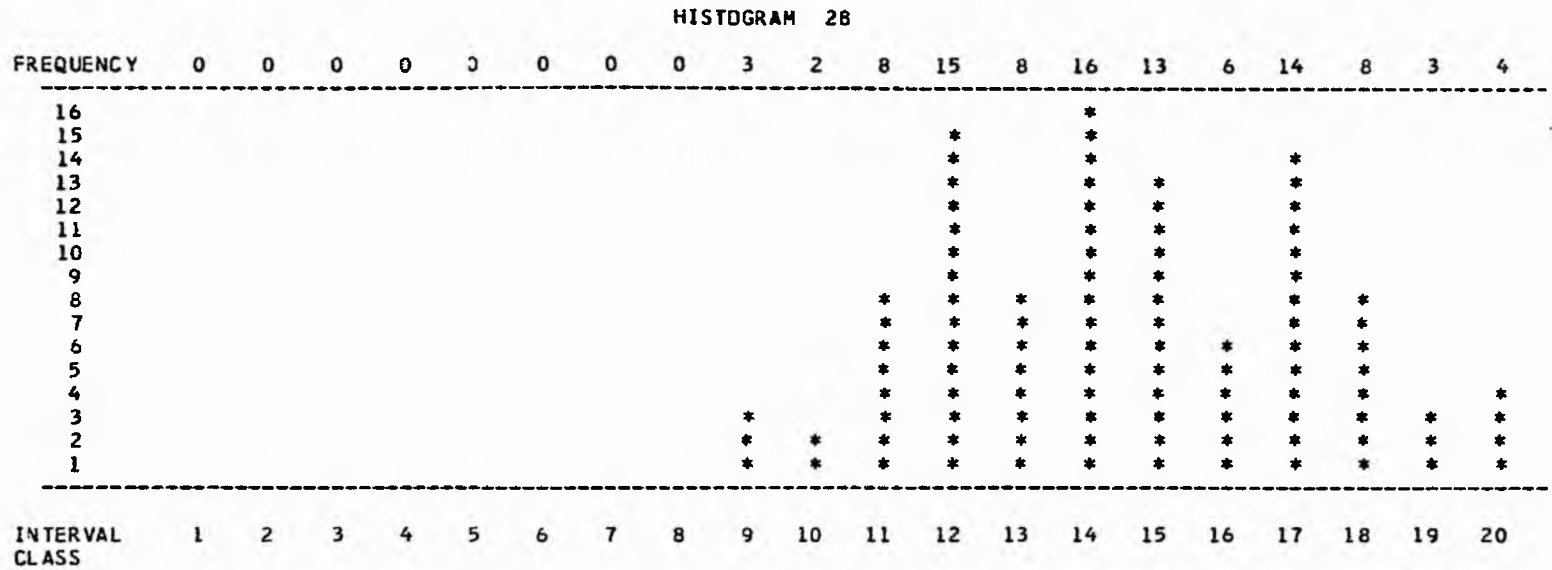


Fig. 93. Histogram for sphericity of pebbles from site one of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.699	0.018	0.134	0.062	2.175

HISTOGRAM 29

```
FREQUENCY   0   0   0   7  23  23  17  11  10   4   2   2   1   0   0   0   0   0   0   0
 ------------------------------------------------------------------------------------------
    23                      *   *
    22                      *   *
    21                      *   *
    20                      *   *
    19                      *   *
    18                      *   *
    17                      *   *   *
    16                      *   *   *
    15                      *   *   *
    14                      *   *   *
    13                      *   *   *
    12                      *   *   *
    11                      *   *   *   *
    10                      *   *   *   *   *
     9                      *   *   *   *   *
     8                      *   *   *   *   *
     7                  *   *   *   *   *   *
     6                  *   *   *   *   *   *
     5                  *   *   *   *   *   *
     4                  *   *   *   *   *   *   *
     3                  *   *   *   *   *   *   *
     2                  *   *   *   *   *   *   *   *   *
     1                  *   *   *   *   *   *   *   *   *   *
 ------------------------------------------------------------------------------------------

INTERVAL    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 94. Histogram for flatness of pebbles from site one of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.874	0.351	0.592	0.849	3.212

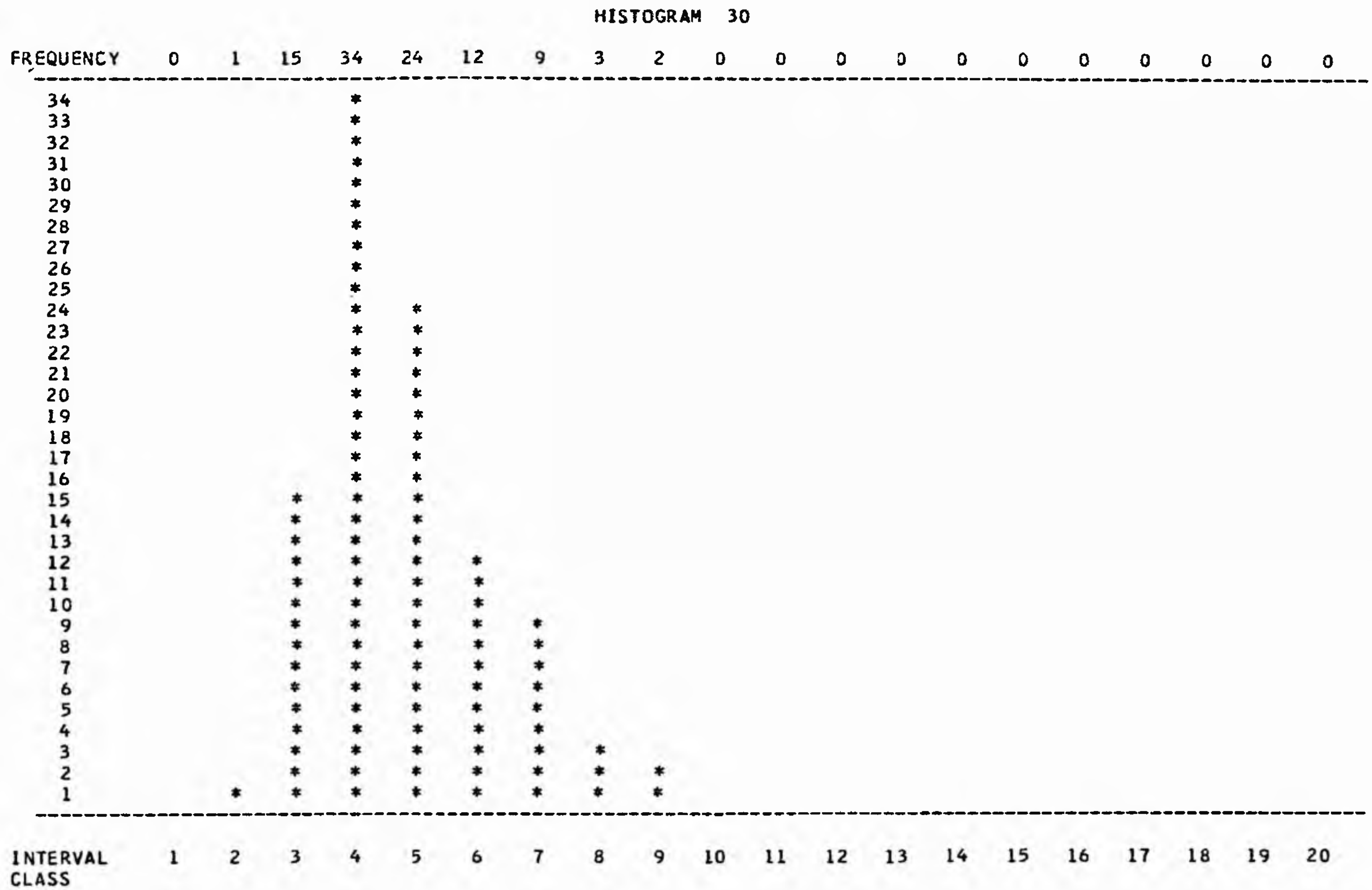


Fig. 95. Histogram for roundness of pebbles from site one of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
212.119	4698.977	68.549	0.869	3.213

```
                              HISTOGRAM  33

FREQUENCY   0   0   0   0   0   0   1   2   7  12  13   9   3  11  11  11  11   6   3   0
-----------------------------------------------------------------------------------------
    13                                          *
    12                                      *   *
    11                                      *   *           *   *   *   *
    10                                      *   *           *   *   *   *
     9                                      *   *   *       *   *   *   *
     8                                      *   *   *       *   *   *   *
     7                                  *   *   *   *       *   *   *   *
     6                                  *   *   *   *       *   *   *   *   *
     5                                  *   *   *   *       *   *   *   *   *
     4                                  *   *   *   *       *   *   *   *   *
     3                                  *   *   *   *   *   *   *   *   *   *   *
     2                              *   *   *   *   *   *   *   *   *   *   *   *
     1                          *   *   *   *   *   *   *   *   *   *   *   *   *
-----------------------------------------------------------------------------------------

INTERVAL    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 96. Histogram for sphericity of pebbles from site two of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.645	0.023	0.153	0.009	1.773

```
                                HISTOGRAM  34

FREQUENCY      0   0   0   3  21  21   8   8  11   7   9   4   5   1   1   0   0   1   0   0
----------------------------------------------------------------------------------------------
        21                     *   *
        20                     *   *
        19                     *   *
        18                     *   *
        17                     *   *
        16                     *   *
        15                     *   *
        14                     *   *
        13                     *   *
        12                     *   *
        11                     *   *           *
        10                     *   *           *
         9                     *   *           *       *
         8                     *   *   *   *   *       *
         7                     *   *   *   *   *   *   *
         6                     *   *   *   *   *   *   *
         5                     *   *   *   *   *   *   *       *
         4                     *   *   *   *   *   *   *   *   *
         3                 *   *   *   *   *   *   *   *   *   *
         2                 *   *   *   *   *   *   *   *   *   *
         1                 *   *   *   *   *   *   *   *   *   *   *   *           *
----------------------------------------------------------------------------------------------

INTERVAL       1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 97. Histogram for flatness of pebbles from site two of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
2.202	0.759	0.871	0.868	3.266

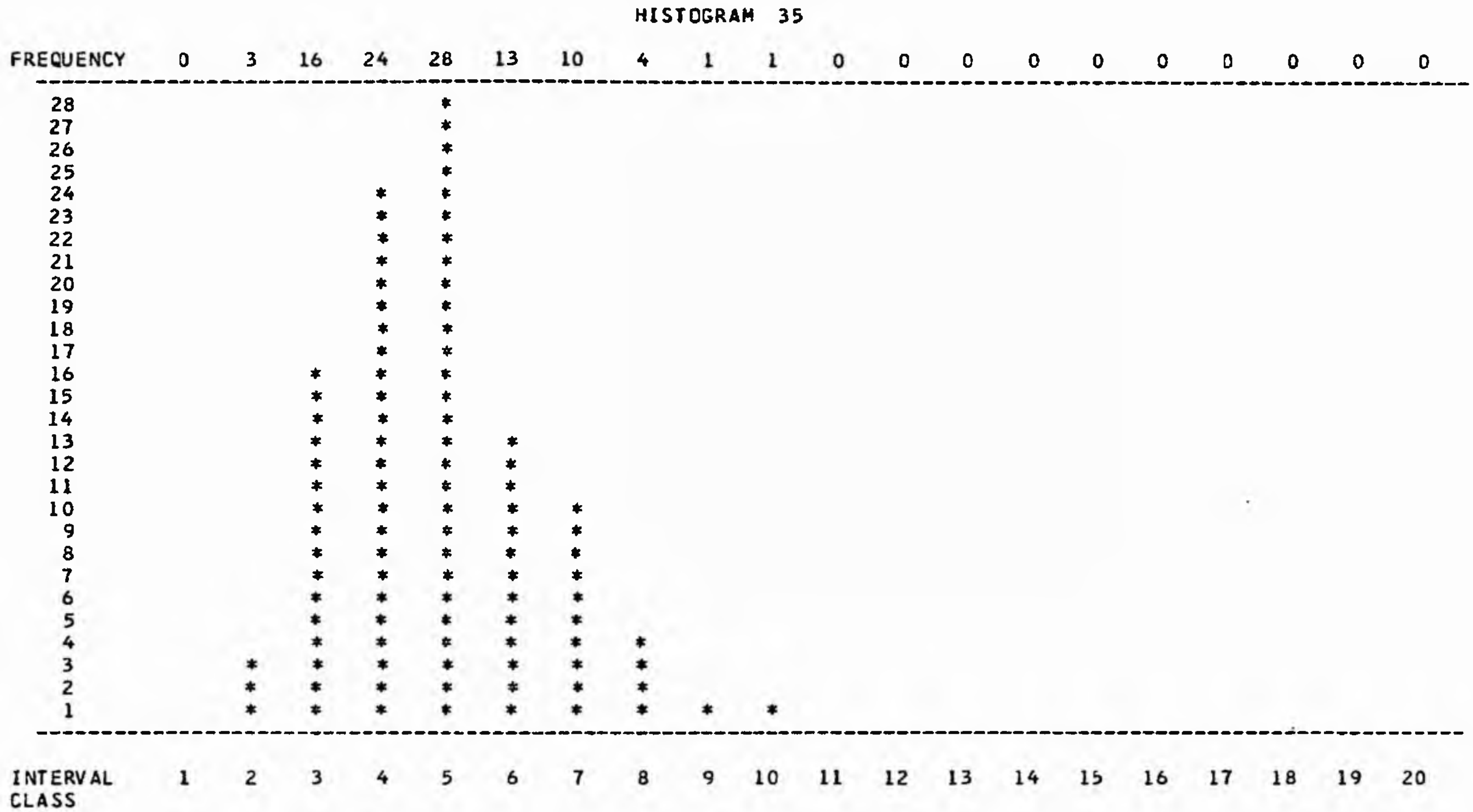


Fig. 98. Histogram for roundness of pebbles from site two of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
216.691	5889.484	76.743	0.745	3.736

HISTOGRAM 38

```
FREQUENCY    0   0   0   0   0   0   0   2   6   3   9  13  11  12  10   8  14   7   4   1
------------------------------------------------------------------------------------------
       14                                                                   *
       13                                               *                   *
       12                                               *       *           *
       11                                               *   *   *           *
       10                                               *   *   *   *       *
        9                                           *   *   *   *   *       *
        8                                           *   *   *   *   *   *   *
        7                                           *   *   *   *   *   *   *   *
        6                                   *       *   *   *   *   *   *   *   *
        5                                   *       *   *   *   *   *   *   *   *
        4                                   *       *   *   *   *   *   *   *   *   *
        3                                   *   *   *   *   *   *   *   *   *   *   *
        2                               *   *   *   *   *   *   *   *   *   *   *   *
        1                               *   *   *   *   *   *   *   *   *   *   *   *   *
------------------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 99. Histogram for sphericity of pebbles from site three of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.678	0.021	0.145	-0.082	2.073

HISTOGRAM 39

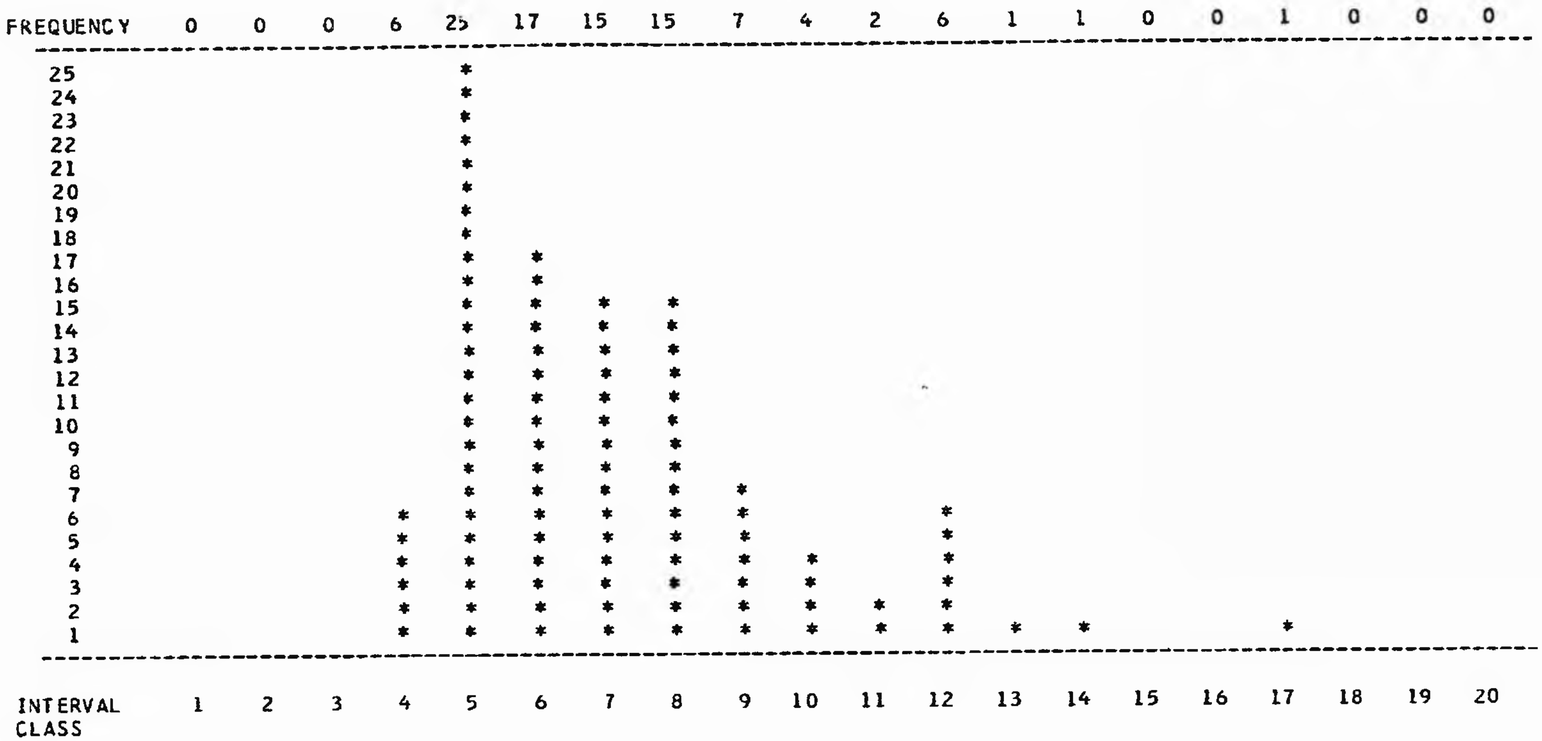


Fig. 100. Histogram for flatness of pebbles from site three of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
2.003	0.559	0.747	1.202	4.362

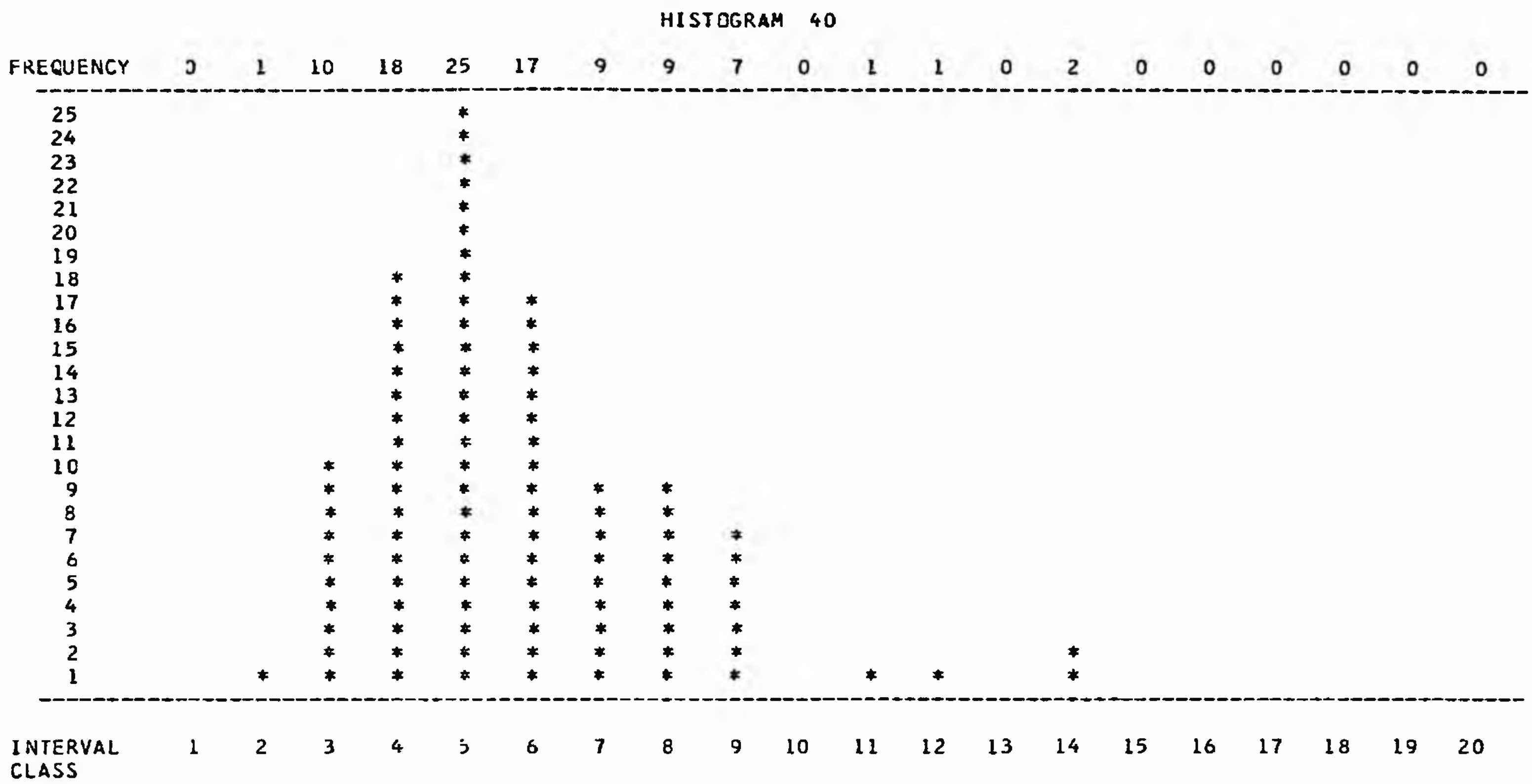


Fig. 101. Histogram for roundness of pebbles from site three of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
262.734	11449.676	107.003	1.440	5.875

```
                              HISTOGRAM 43

FREQUENCY   0   0   0   0   0   0   0   1   2   5  11  14  13   9   3   9  14  13   4   2
------------------------------------------------------------------------------------------
   14                                                   *                   *
   13                                                   *   *               *   *
   12                                                   *   *               *   *
   11                                               *   *   *               *   *
   10                                               *   *   *               *   *
    9                                               *   *   *   *       *   *   *
    8                                               *   *   *   *       *   *   *
    7                                               *   *   *   *       *   *   *
    6                                               *   *   *   *       *   *   *
    5                                           *   *   *   *   *       *   *   *
    4                                           *   *   *   *   *       *   *   *   *
    3                                           *   *   *   *   *   *   *   *   *   *
    2                                       *   *   *   *   *   *   *   *   *   *   *   *
    1                                   *   *   *   *   *   *   *   *   *   *   *   *   *
------------------------------------------------------------------------------------------

INTERVAL    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 102. Histogram for sphericity of pebbles from site four of pediment B.

```
MOMENT MEASURES

     MEAN      VARIANCE       STAN. DEV.     SKEWNESS     KURTOSIS
      0.694        0.021          0.146        0.019         1.773
```

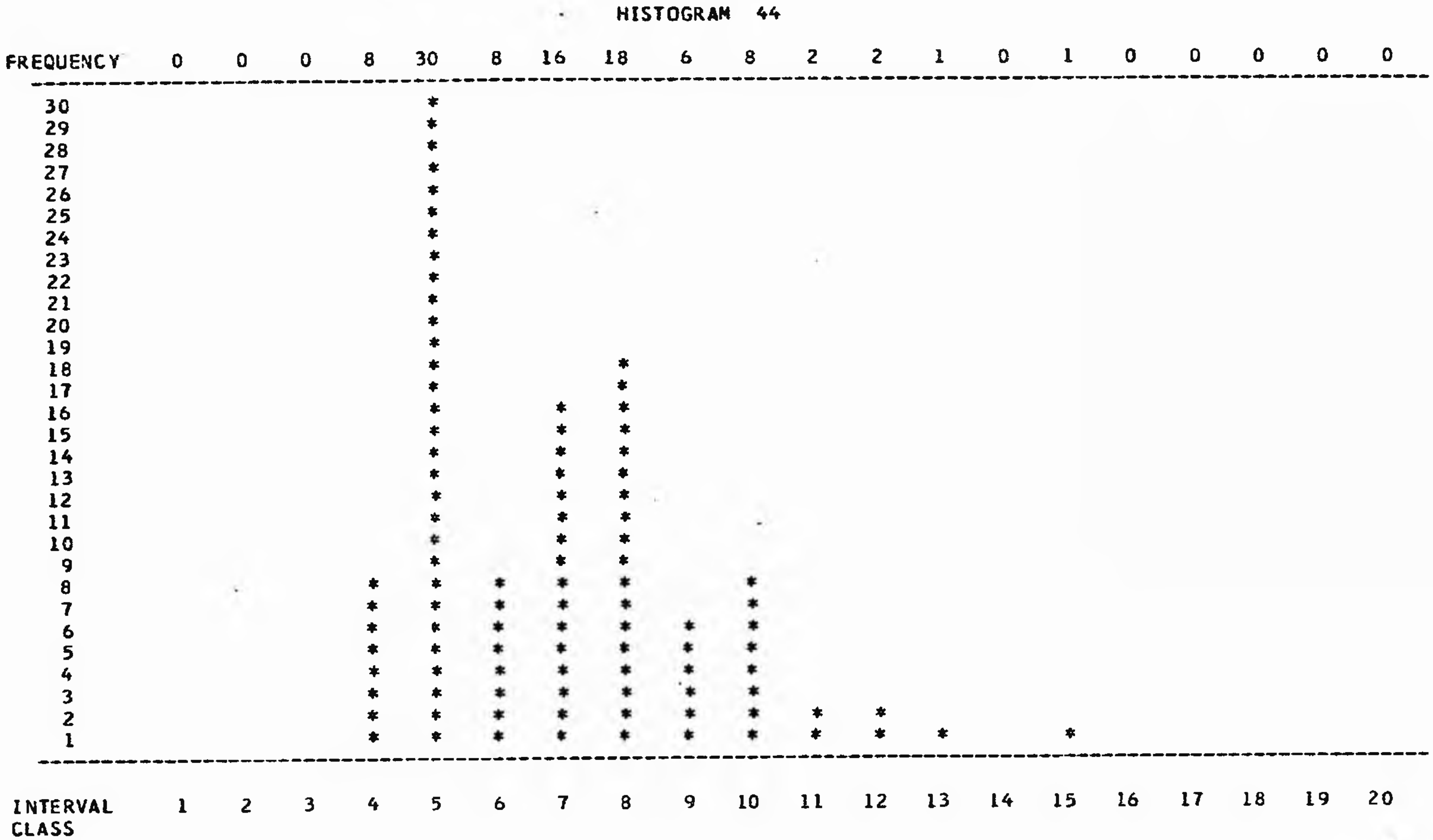


Fig. 103. Histogram for flatness of pebbles from site four of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.922	0.447	0.668	0.877	3.532

HISTOGRAM 45

```
FREQUENCY    0   3  12  20  21  16   5   4   8   5   2   2   1   0   1   0   0   0   0   0
--------------------------------------------------------------------------------------------
        21                   *
        20               *   *
        19               *   *
        18               *   *
        17               *   *
        16               *   *   *
        15               *   *   *
        14               *   *   *
        13               *   *   *
        12           *   *   *   *
        11           *   *   *   *
        10           *   *   *   *
         9           *   *   *   *
         8           *   *   *   *           *
         7           *   *   *   *           *
         6           *   *   *   *           *
         5           *   *   *   *   *       *   *
         4           *   *   *   *   *   *   *   *
         3       *   *   *   *   *   *   *   *   *
         2       *   *   *   *   *   *   *   *   *   *   *
         1       *   *   *   *   *   *   *   *   *   *   *   *       *
--------------------------------------------------------------------------------------------
INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 104. Histogram for roundness of pebbles from site four of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
263.636	16793.129	129.588	1.209	4.192

HISTOGRAM 48

```
FREQUENCY    0   0   0   0   0   0   0   1   1   6  10   7  11  17  16   9  12   4   3   3
          --------------------------------------------------------------------------------
      17                                                     *
      16                                                     *   *
      15                                                     *   *
      14                                                     *   *
      13                                                     *   *
      12                                                     *   *       *
      11                                                 *   *   *       *
      10                                         *       *   *   *       *
       9                                         *       *   *   *   *   *
       8                                         *       *   *   *   *   *
       7                                         *   *   *   *   *   *   *
       6                                     *   *   *   *   *   *   *   *
       5                                     *   *   *   *   *   *   *   *
       4                                     *   *   *   *   *   *   *   *   *
       3                                     *   *   *   *   *   *   *   *   *   *   *
       2                                     *   *   *   *   *   *   *   *   *   *   *
       1                             *   *   *   *   *   *   *   *   *   *   *   *   *
          --------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 105. Histogram for sphericity of pebbles from site five of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.688	0.017	0.132	-0.014	2.420

HISTOGRAM 49

```
FREQUENCY      0   0   0   7  20  26  19   6   9   8   3   0   1   0   0   1   0   0   0   0
------------------------------------------------------------------------------------------------
          26                       *
          25                       *
          24                       *
          23                       *
          22                       *
          21                       *
          20                   *   *
          19                   *   *   *
          18                   *   *   *
          17                   *   *   *
          16                   *   *   *
          15                   *   *   *
          14                   *   *   *
          13                   *   *   *
          12                   *   *   *
          11                   *   *   *
          10                   *   *   *
           9                   *   *   *       *
           8                   *   *   *       *   *
           7               *   *   *   *       *   *
           6               *   *   *   *   *   *   *
           5               *   *   *   *   *   *   *
           4               *   *   *   *   *   *   *
           3               *   *   *   *   *   *   *   *
           2               *   *   *   *   *   *   *   *
           1               *   *   *   *   *   *   *   *       *           *
------------------------------------------------------------------------------------------------
INTERVAL       1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 106. Histogram for flatness of pebbles from site five of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.918	0.406	0.637	1.363	5.757

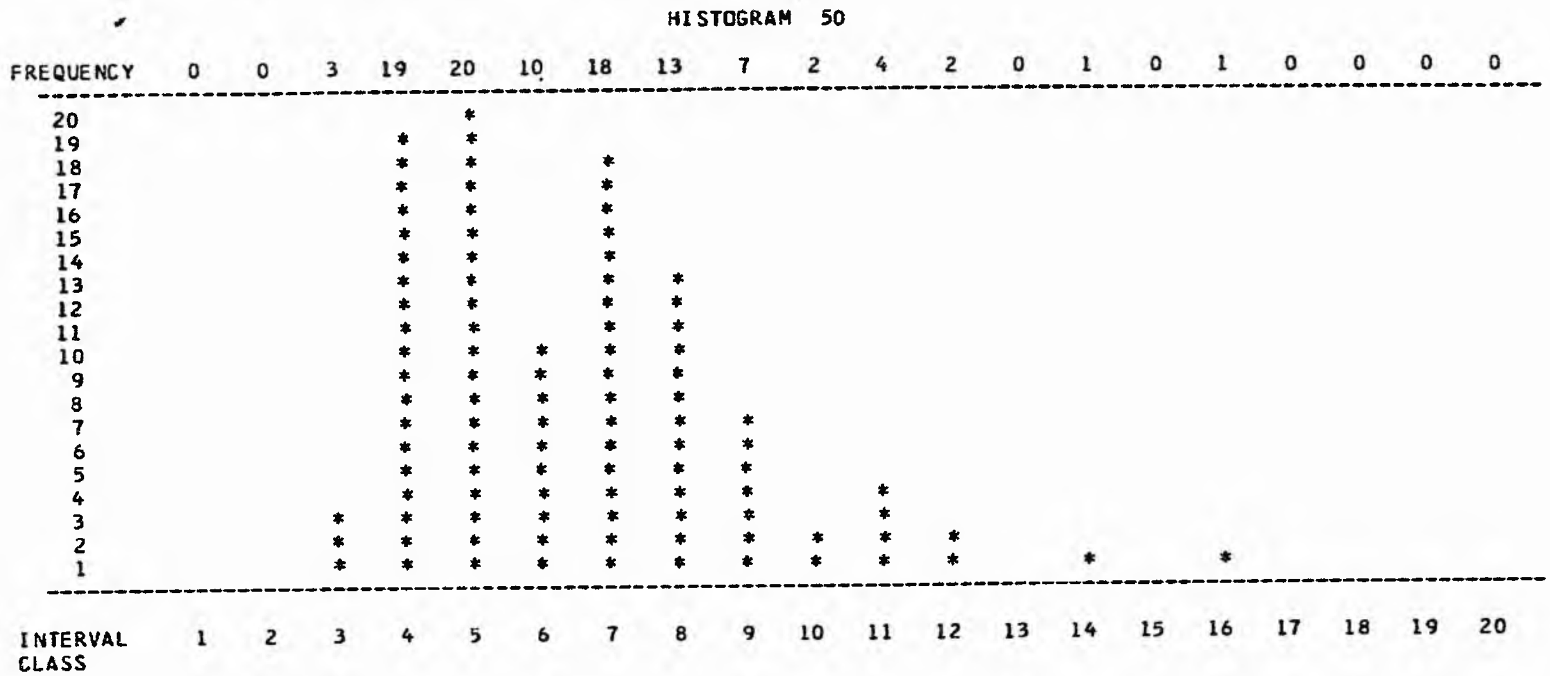


Fig. 107. Histogram for roundness of pebbles from site five of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
299.470	13656.332	116.860	1.148	4.781

HISTOGRAM 53

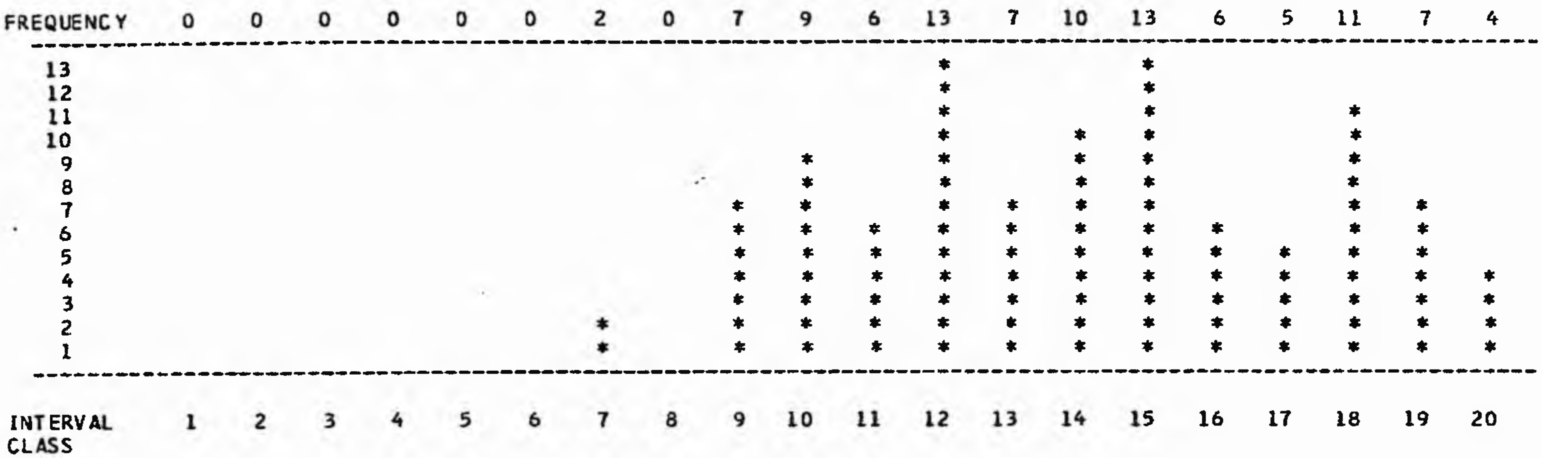


Fig. 108. Histogram for sphericity of pebbles from site six of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.679	0.027	0.165	-0.006	1.950

```
                                HISTOGRAM 54

FREQUENCY    0   0   0  14  18  17  11  12   5   8   5   3   3   2   0   0   2   0   0   0
          --------------------------------------------------------------------------------
        18                   *
        17                   *   *
        16                   *   *
        15                   *   *
        14               *   *   *
        13               *   *   *
        12               *   *   *       *
        11               *   *   *   *   *
        10               *   *   *   *   *
         9               *   *   *   *   *
         8               *   *   *   *   *       *
         7               *   *   *   *   *       *
         6               *   *   *   *   *       *
         5               *   *   *   *   *   *   *   *
         4               *   *   *   *   *   *   *   *
         3               *   *   *   *   *   *   *   *   *   *
         2               *   *   *   *   *   *   *   *   *   *   *           *
         1               *   *   *   *   *   *   *   *   *   *   *           *
          --------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 109. Histogram flatness of pebbles from site six of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
2.059	0.756	0.870	1.133	4.029

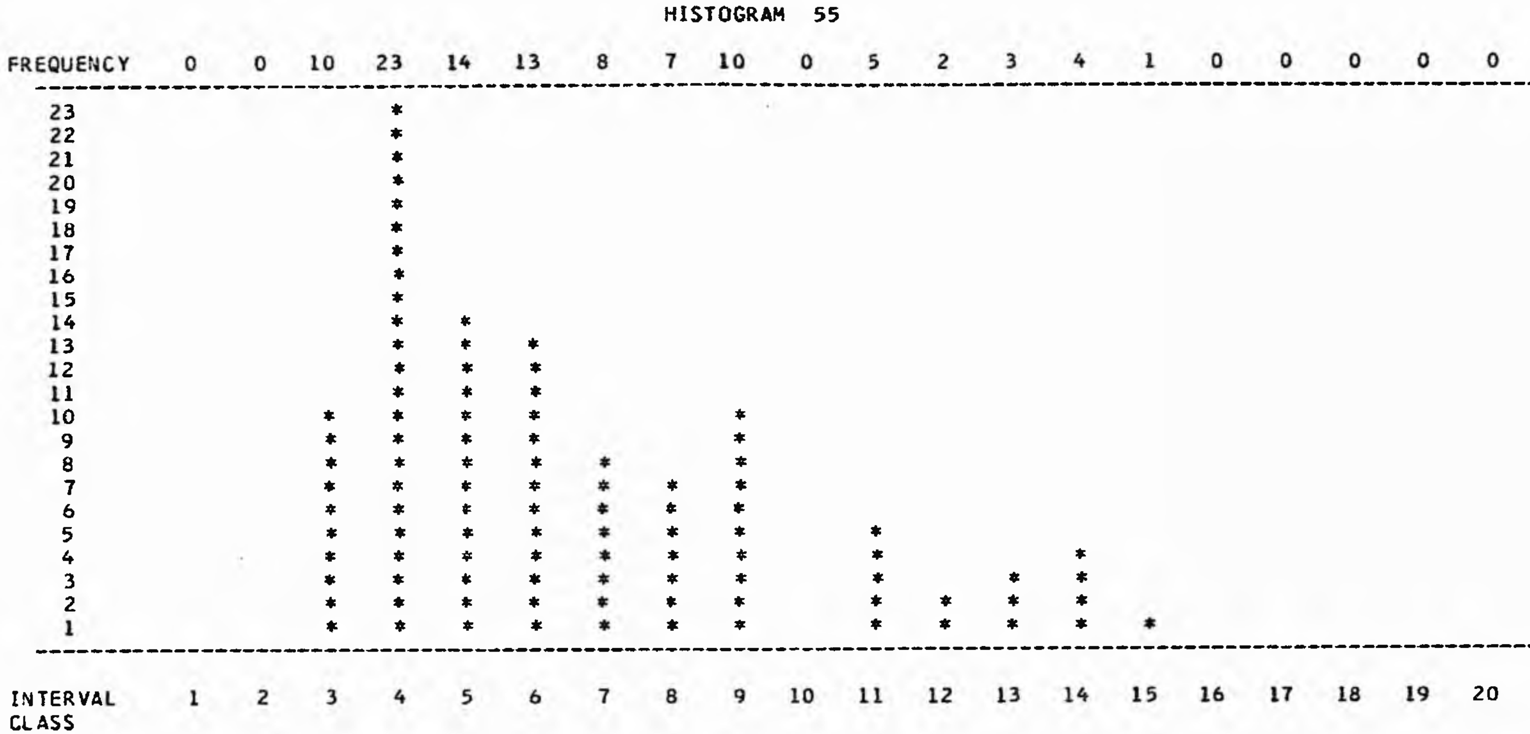


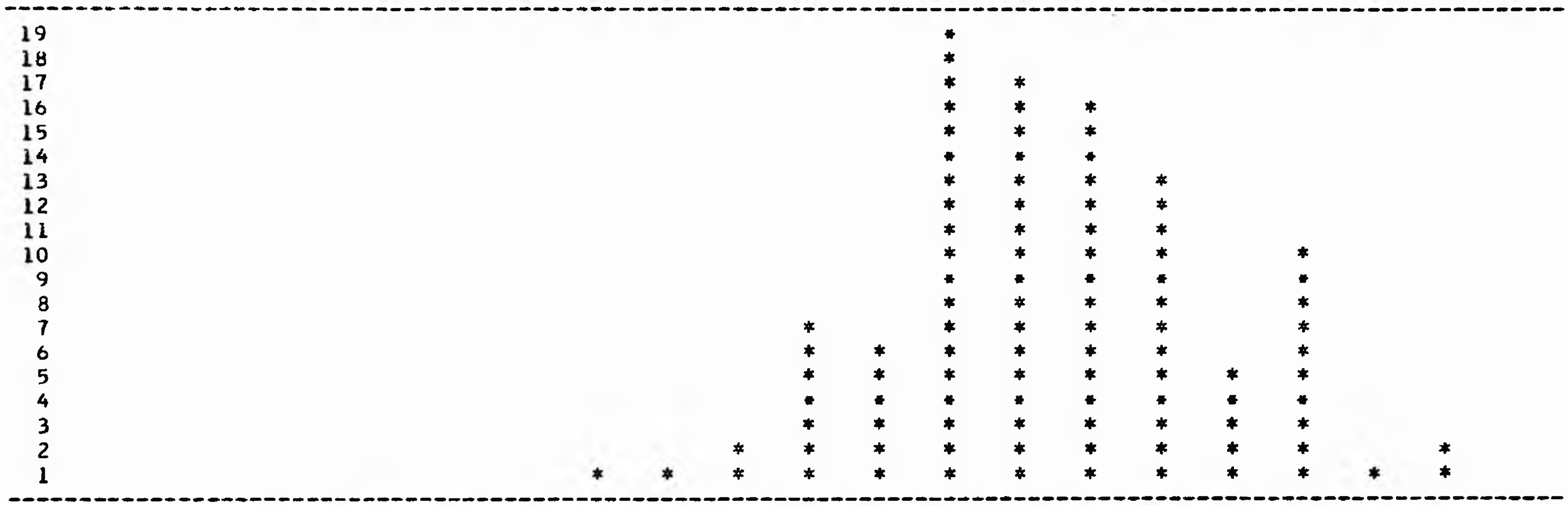
Fig. 110. Histogram for roundness of pebbles from site six of pediment B.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
299.515	24174.754	155.482	0.974	2.960

HISTOGRAM 3

FREQUENCY	0	0	0	0	0	0	1	1	2	7	6	19	17	16	13	5	10	1	2	0



INTERVAL CLASS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Fig. 111. Histogram for sphericity of pebbles from site one of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.649	0.014	0.116	0.049	5.599

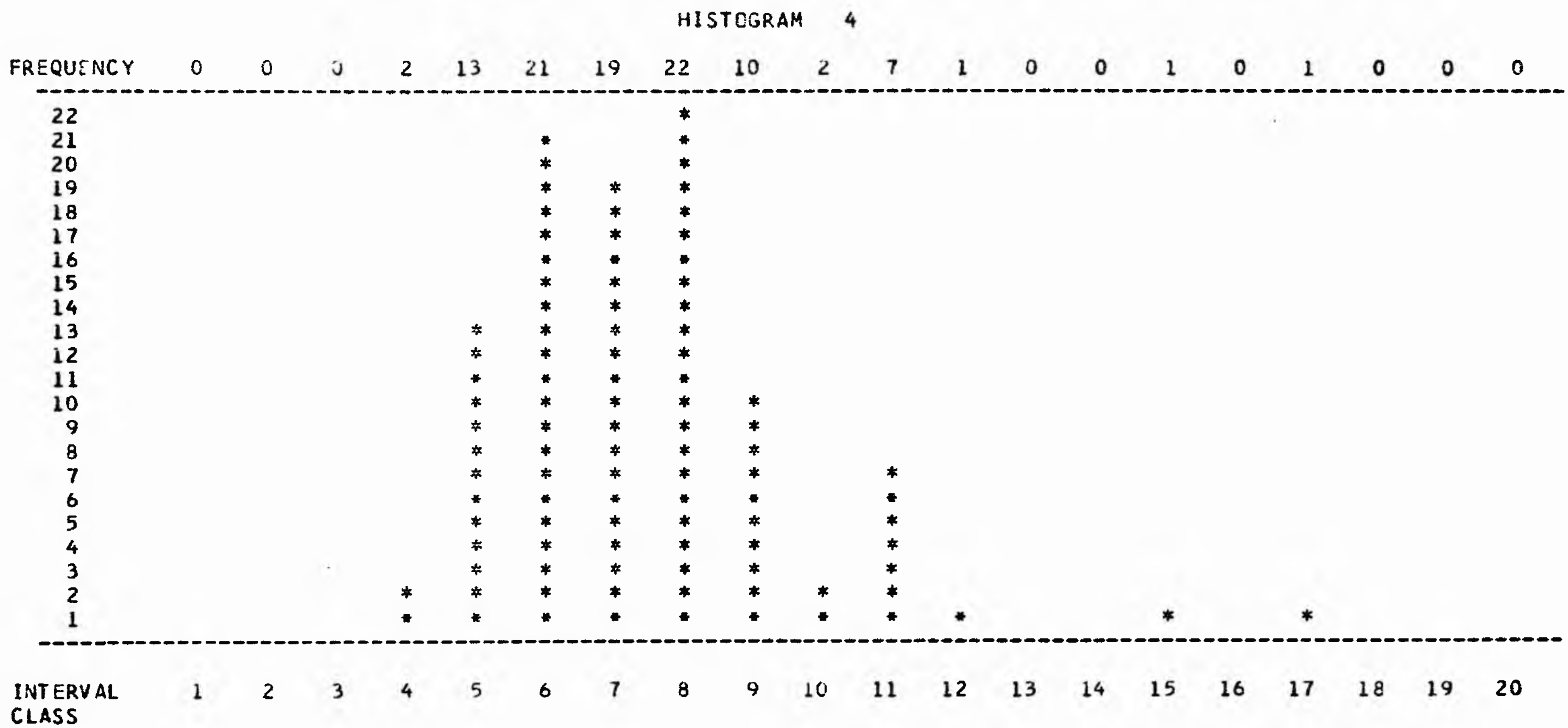


Fig. 112. Histogram for flatness of pebbles from site one of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
2.141	0.568	0.754	2.373	23.860

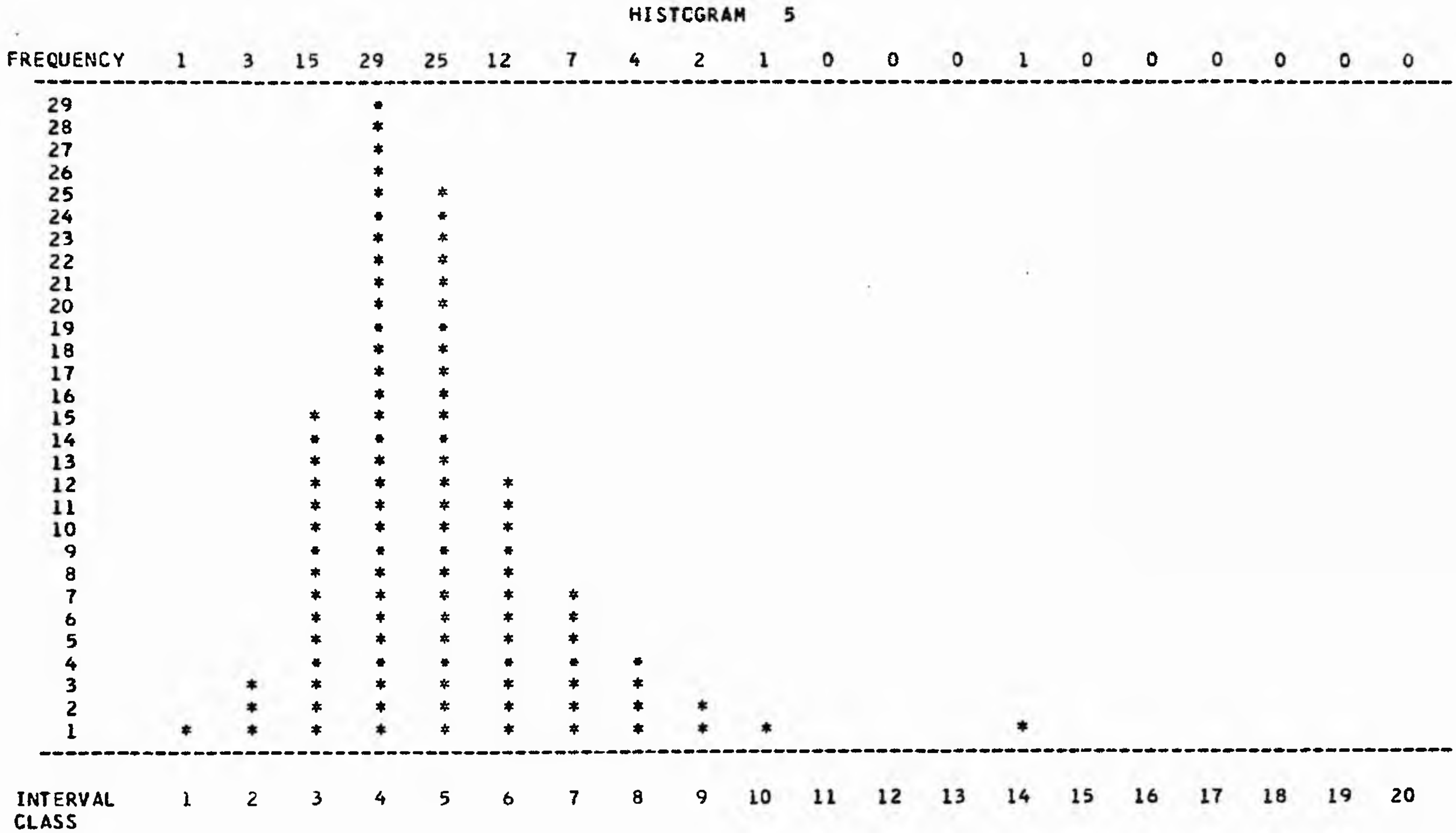


Fig. 113. Histogram for roundness of pebbles from site one of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
215.312	8661.031	93.065	1.707	18.168

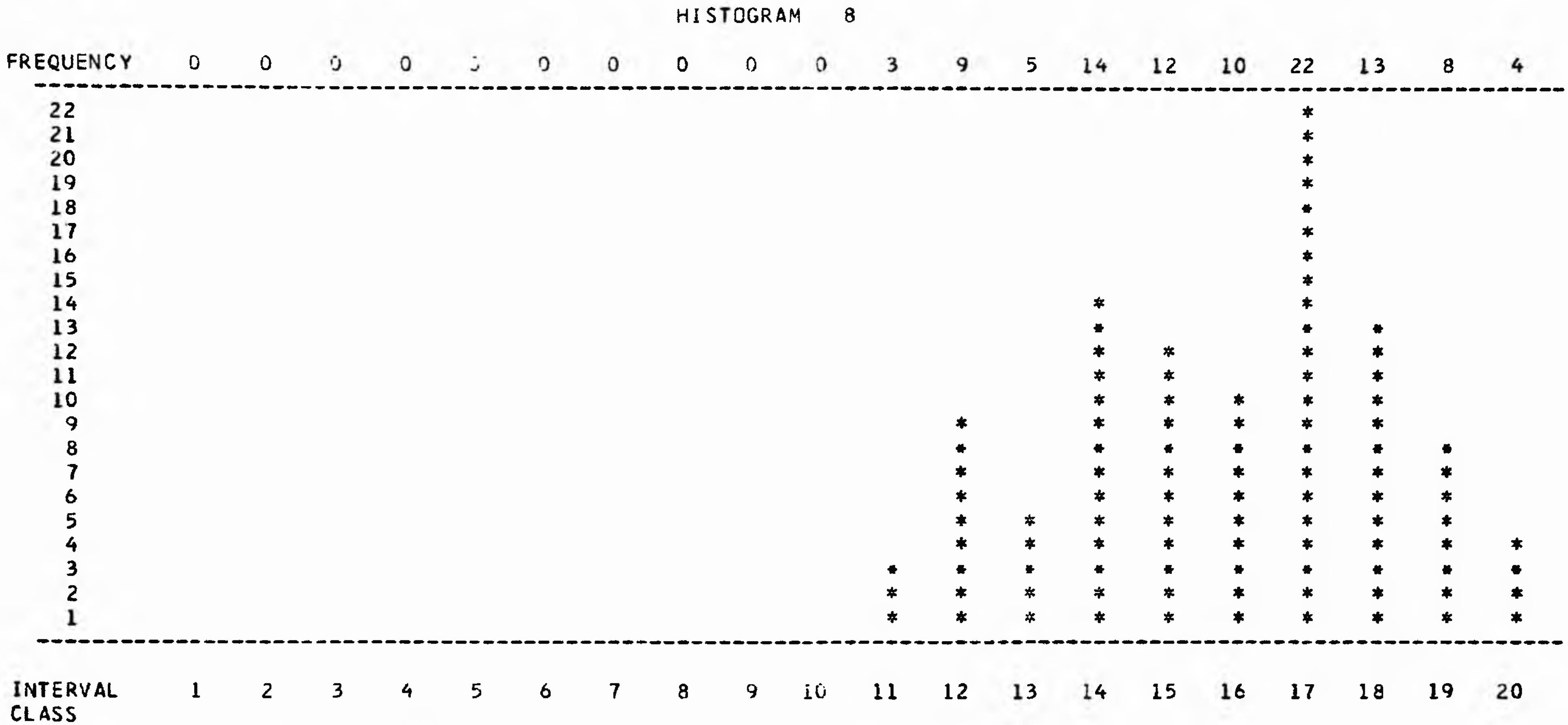


Fig. 114. Histogram for sphericity of pebbles from site two of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.765	0.013	0.114	-0.246	4.338

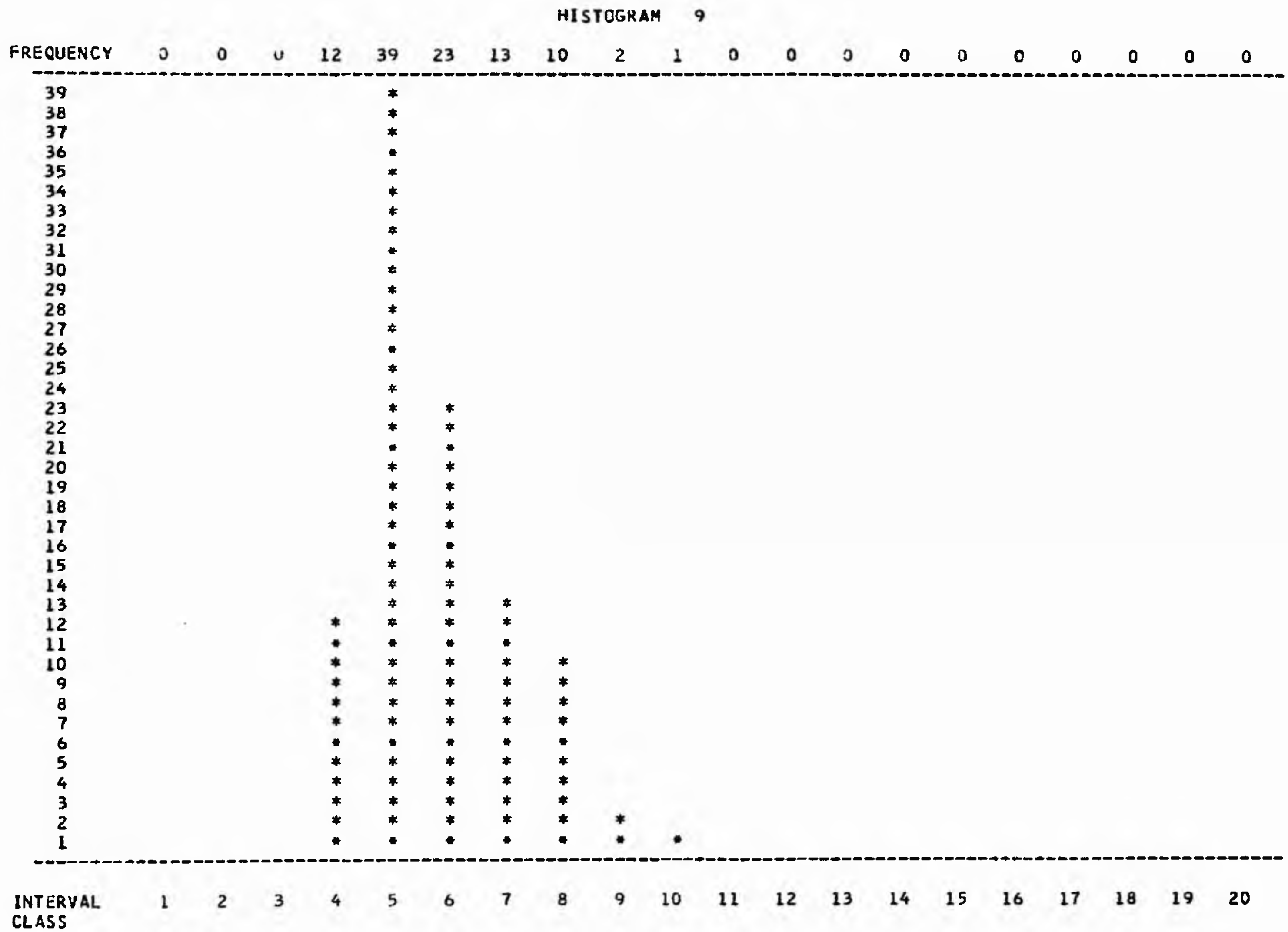


Fig. 115. Histogram for flatness of pebbles from site two of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.571	0.149	0.386	0.897	6.107

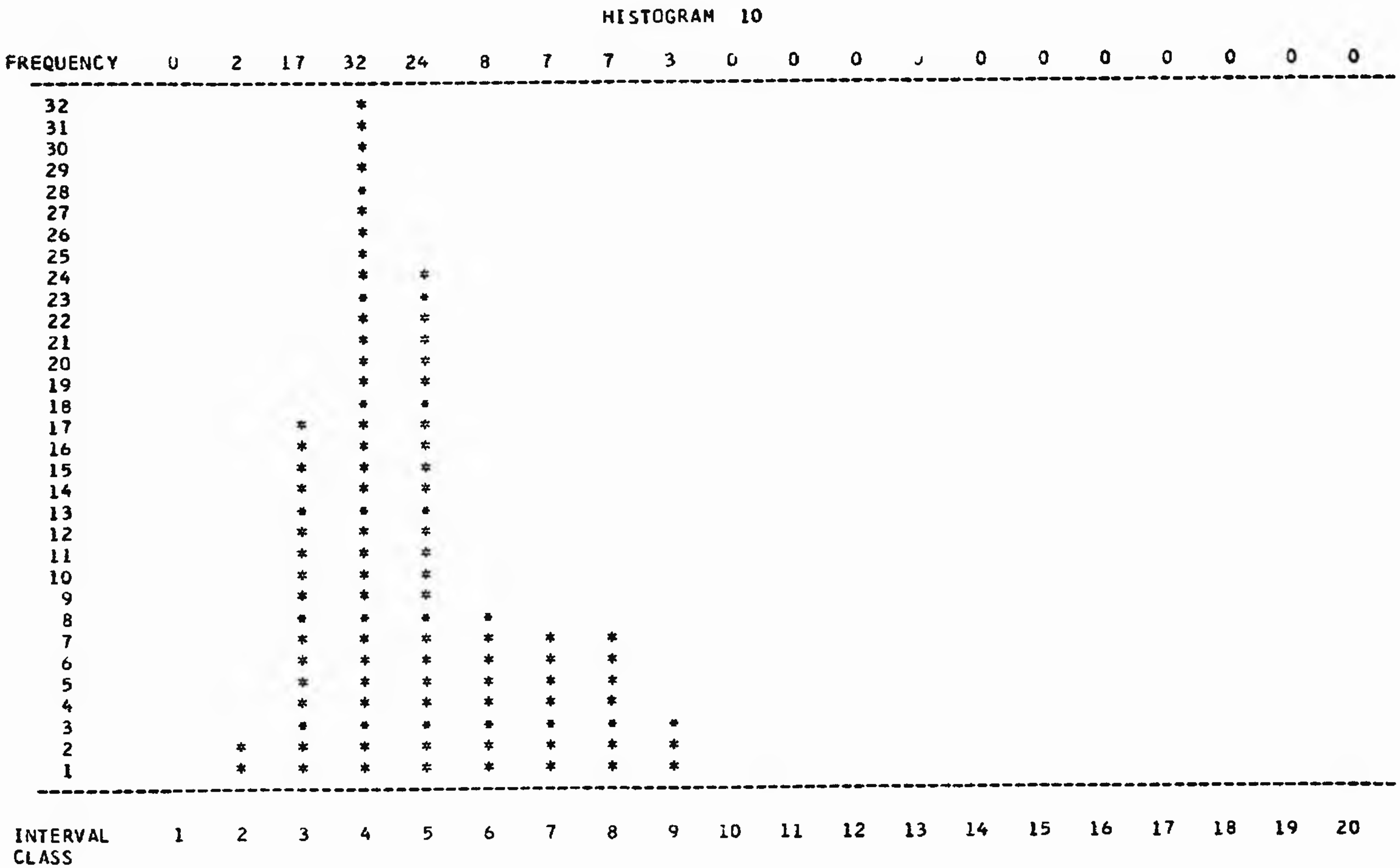


Fig. 116. Histogram for roundness of pebbles from site two of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
215.711	5960.621	77.205	0.876	5.705

HISTOGRAM 13

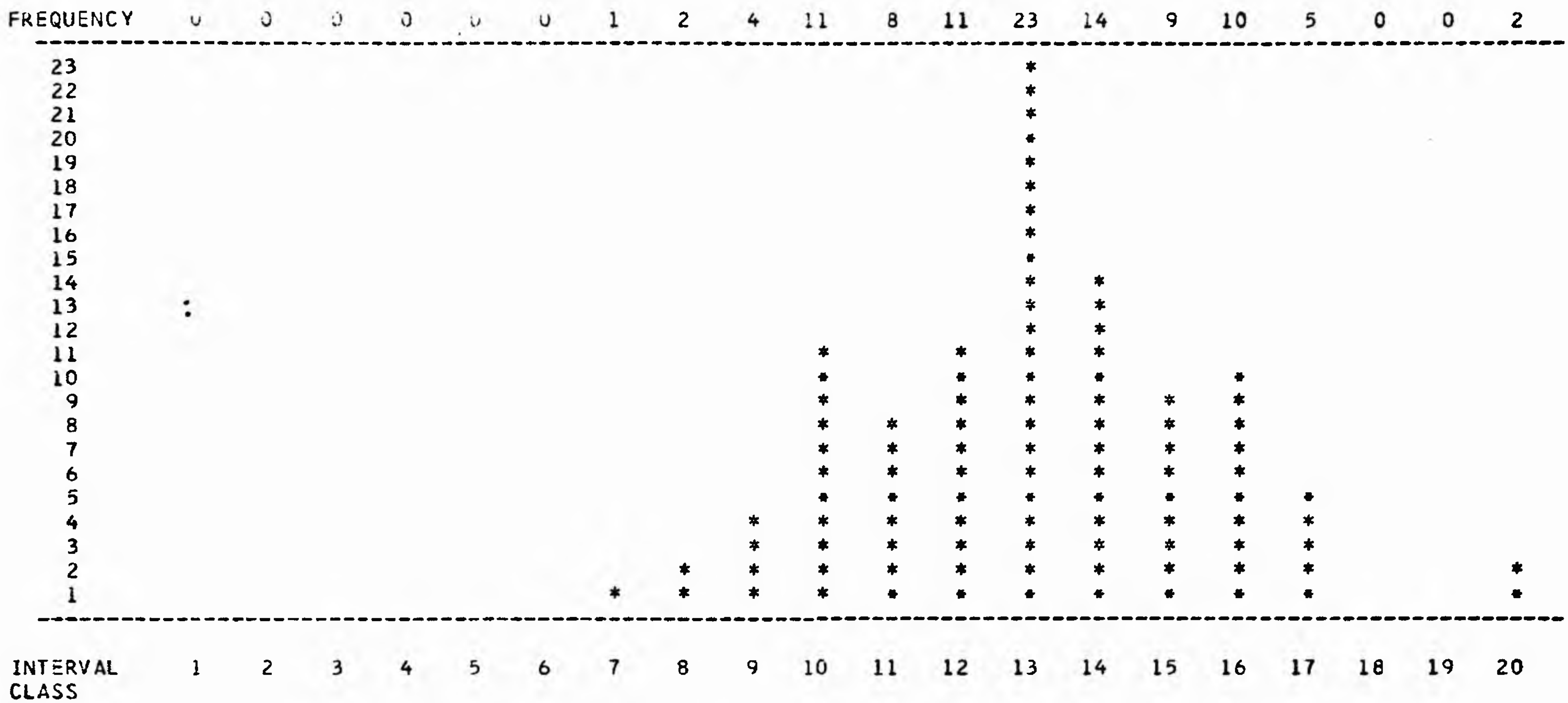


Fig. 117. Histogram for sphericity of pebbles from site three of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.624	0.015	0.122	0.070	5.977

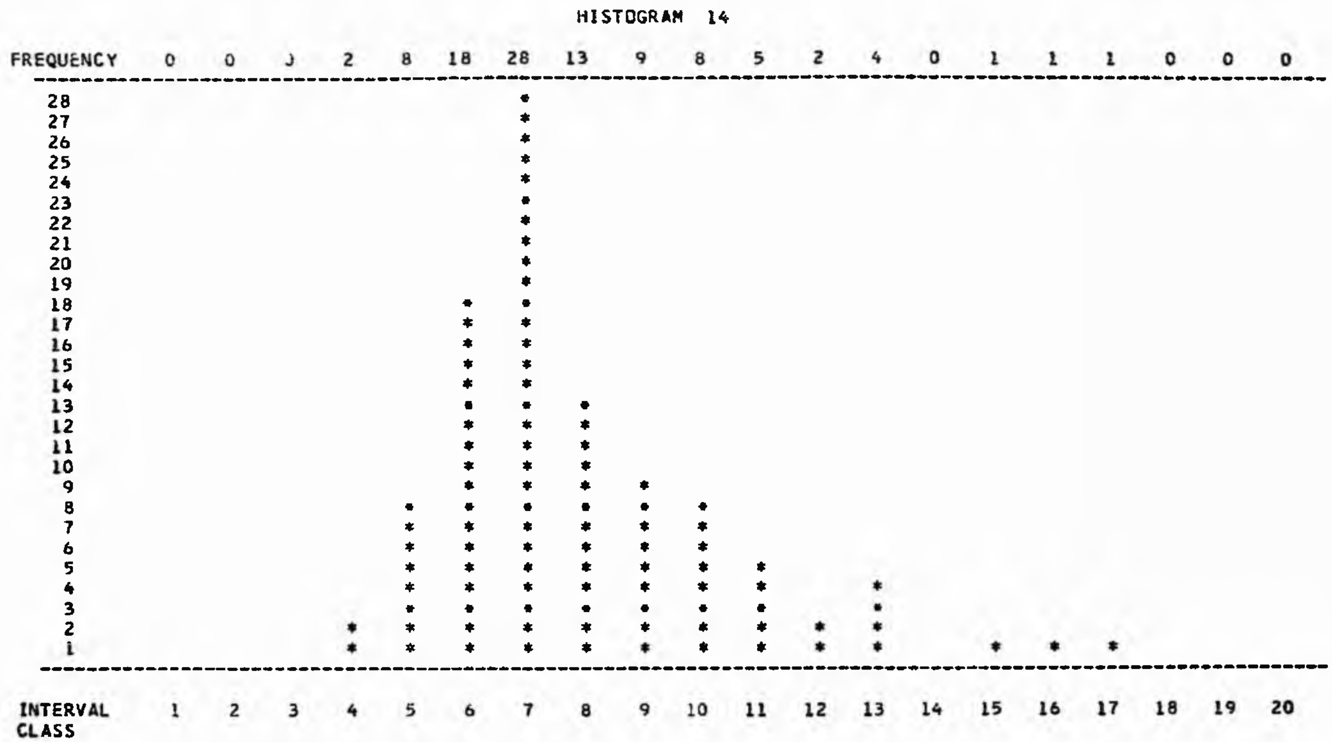


Fig. 118. Histogram for flatness of pebbles from site three of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
2.241	0.553	0.744	1.351	10.205

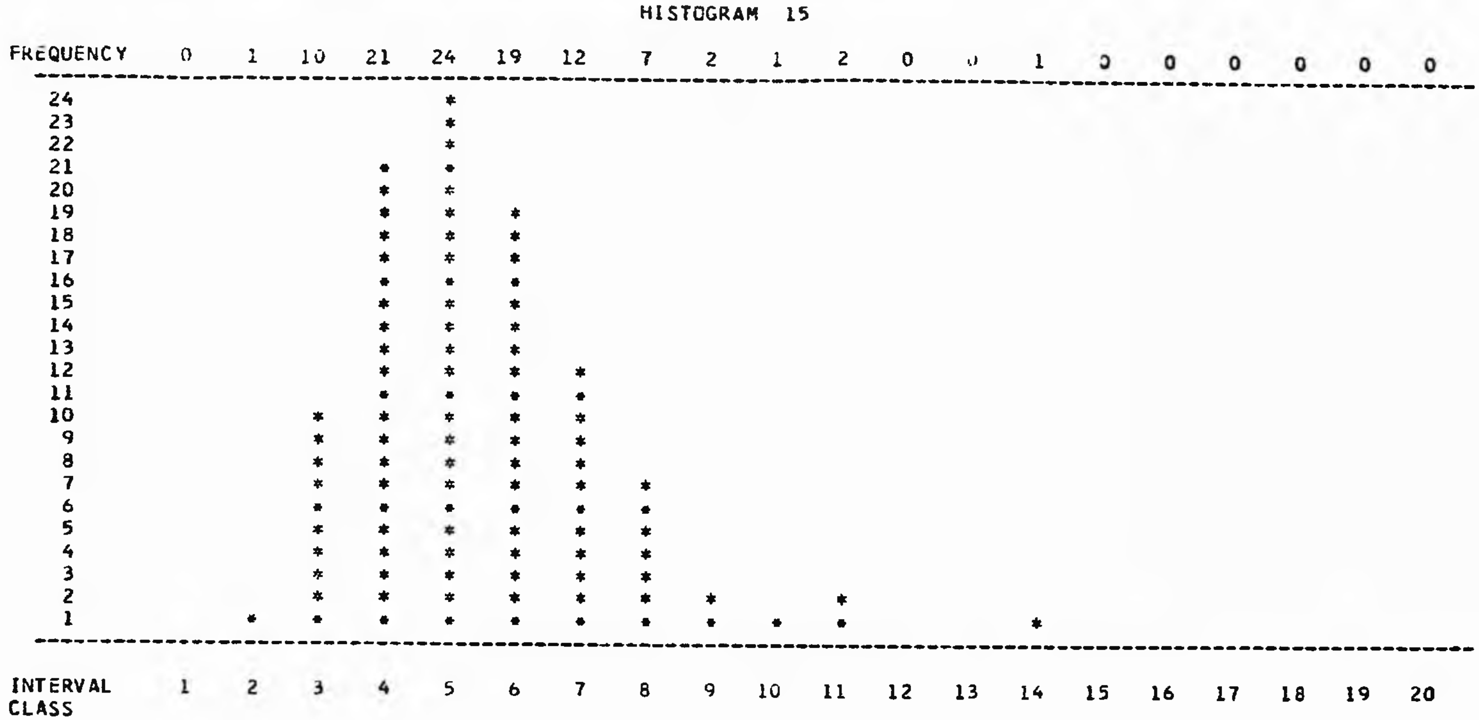


Fig. 119. Histogram for roundness of pebbles from site three of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
252.065	8945.473	94.581	1.347	11.563

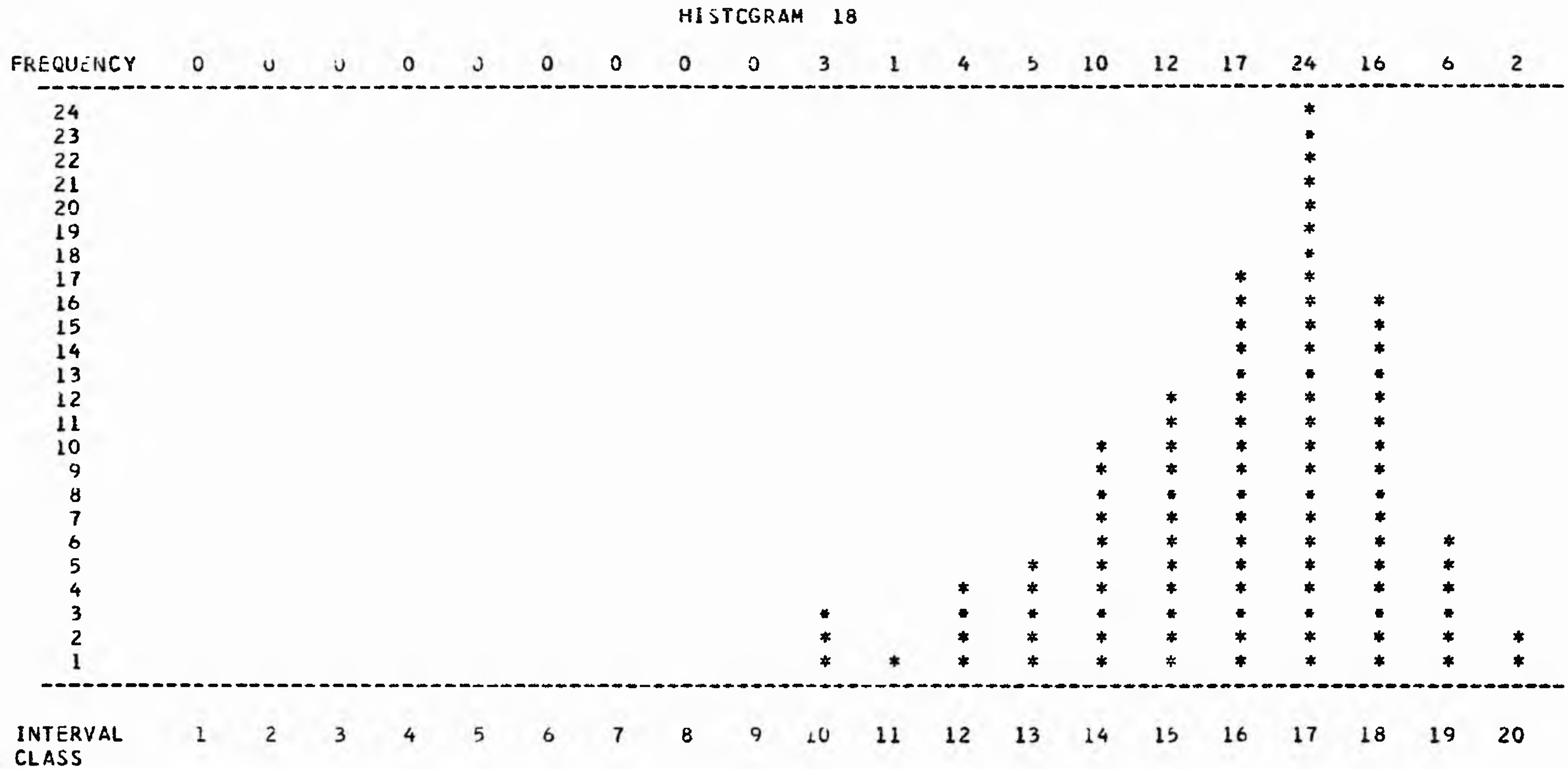


Fig. 120. Histogram for sphericity of pebbles from site four of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.770	0.012	0.108	-0.793	6.491

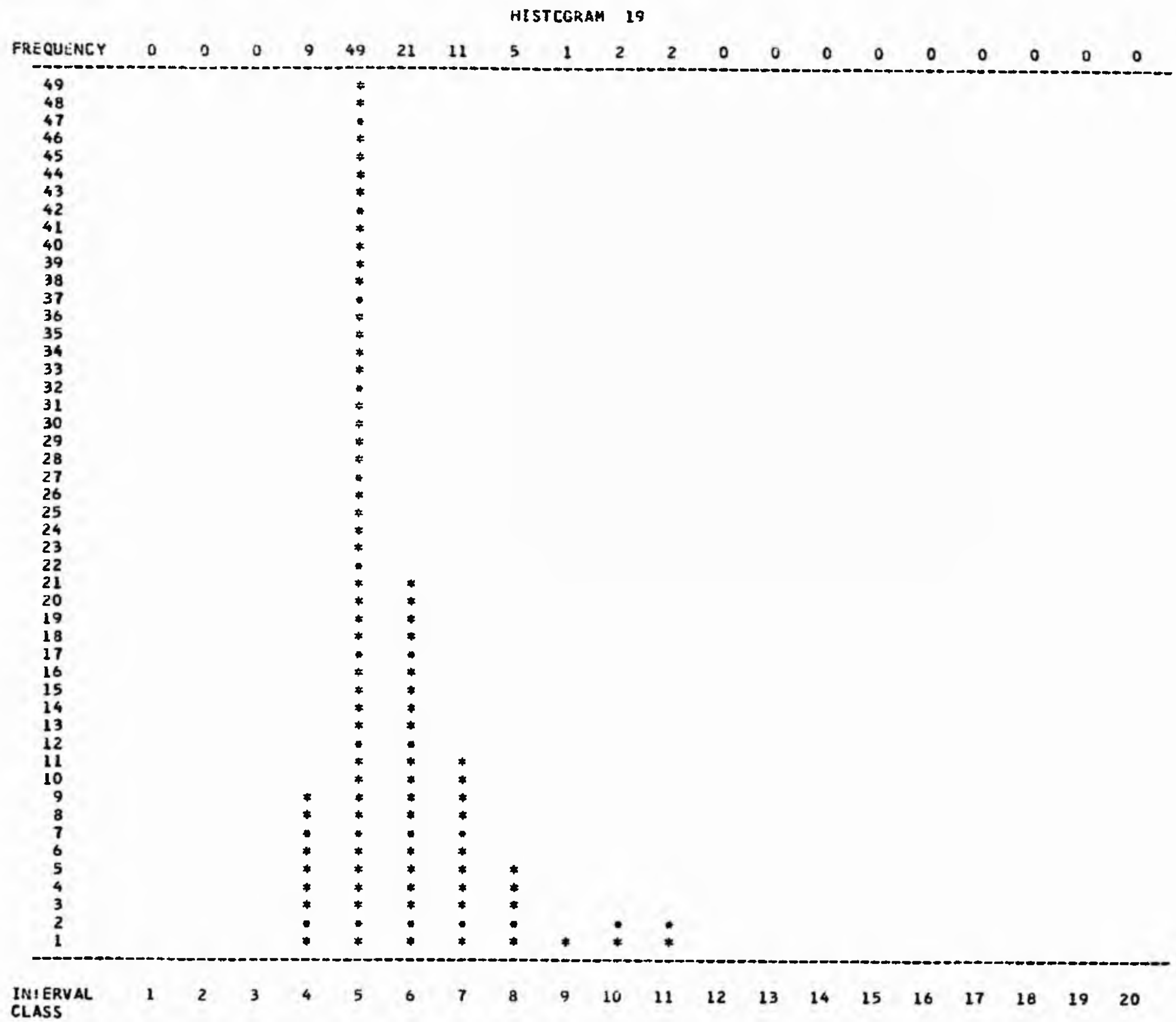


Fig. 121. Histogram for flatness of pebbles from site four of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.557	0.172	0.415	1.872	13.779

```
                                        HISTOGRAM  20

FREQUENCY   0   3  10  16  23  16  14  10   5   1   2   0   0   0   0   0   0   0   0   0
-----------------------------------------------------------------------------------------
   23                       *
   22                       *
   21                       *
   20                       *
   19                       *
   18                       *
   17                       *
   16                   *   *   *
   15                   *   *   *
   14                   *   *   *   *
   13                   *   *   *   *
   12                   *   *   *   *
   11                   *   *   *   *
   10               *   *   *   *   *   *
    9               *   *   *   *   *   *
    8               *   *   *   *   *   *
    7               *   *   *   *   *   *
    6               *   *   *   *   *   *
    5               *   *   *   *   *   *   *
    4               *   *   *   *   *   *   *
    3           *   *   *   *   *   *   *   *
    2           *   *   *   *   *   *   *   *       *
    1           *   *   *   *   *   *   *   *   *   *
-----------------------------------------------------------------------------------------

INTERVAL    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 122. Histogram for roundness of pebbles from site four of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
254.064	9431.180	97.114	0.413	5.295

HISTOGRAM 23

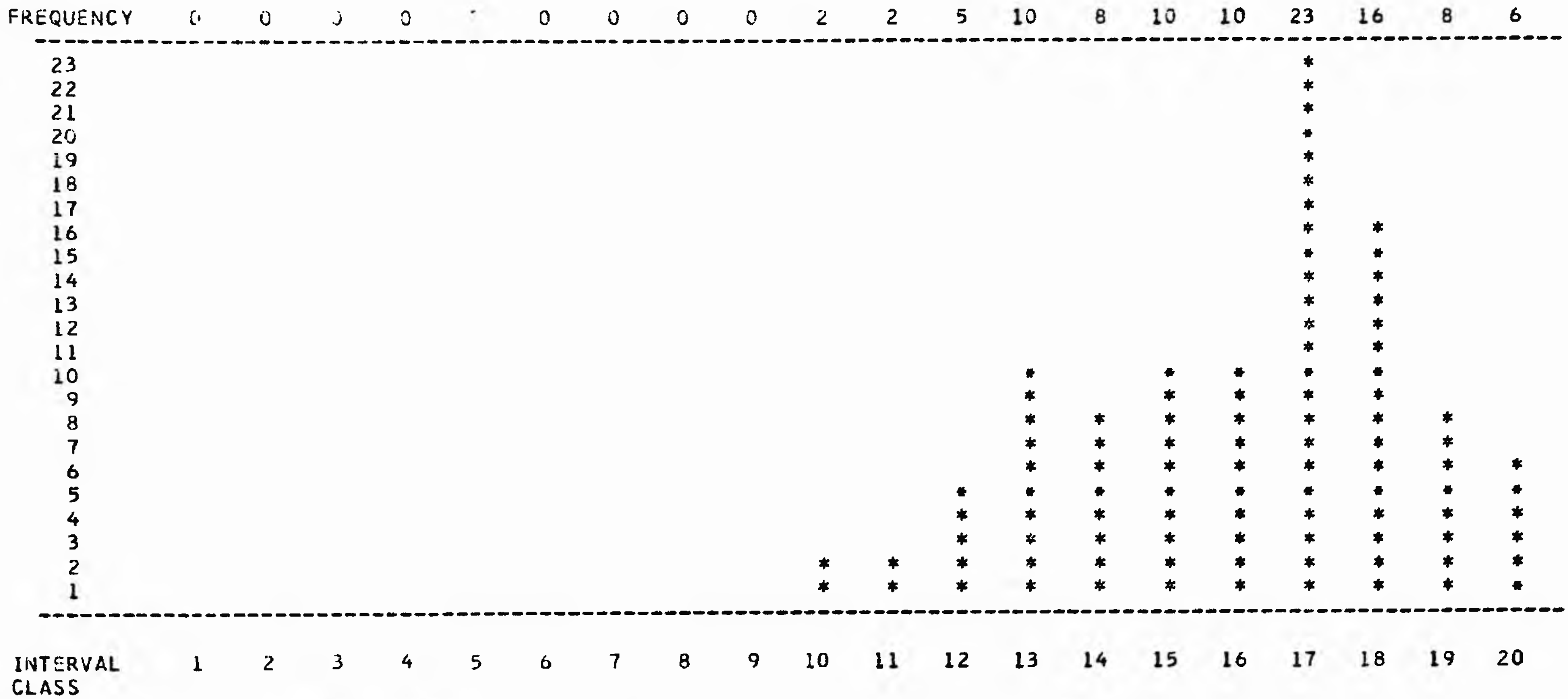


Fig. 123. Histogram for sphericity of pebbles from site five of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.778	0.014	0.120	-0.520	4.777

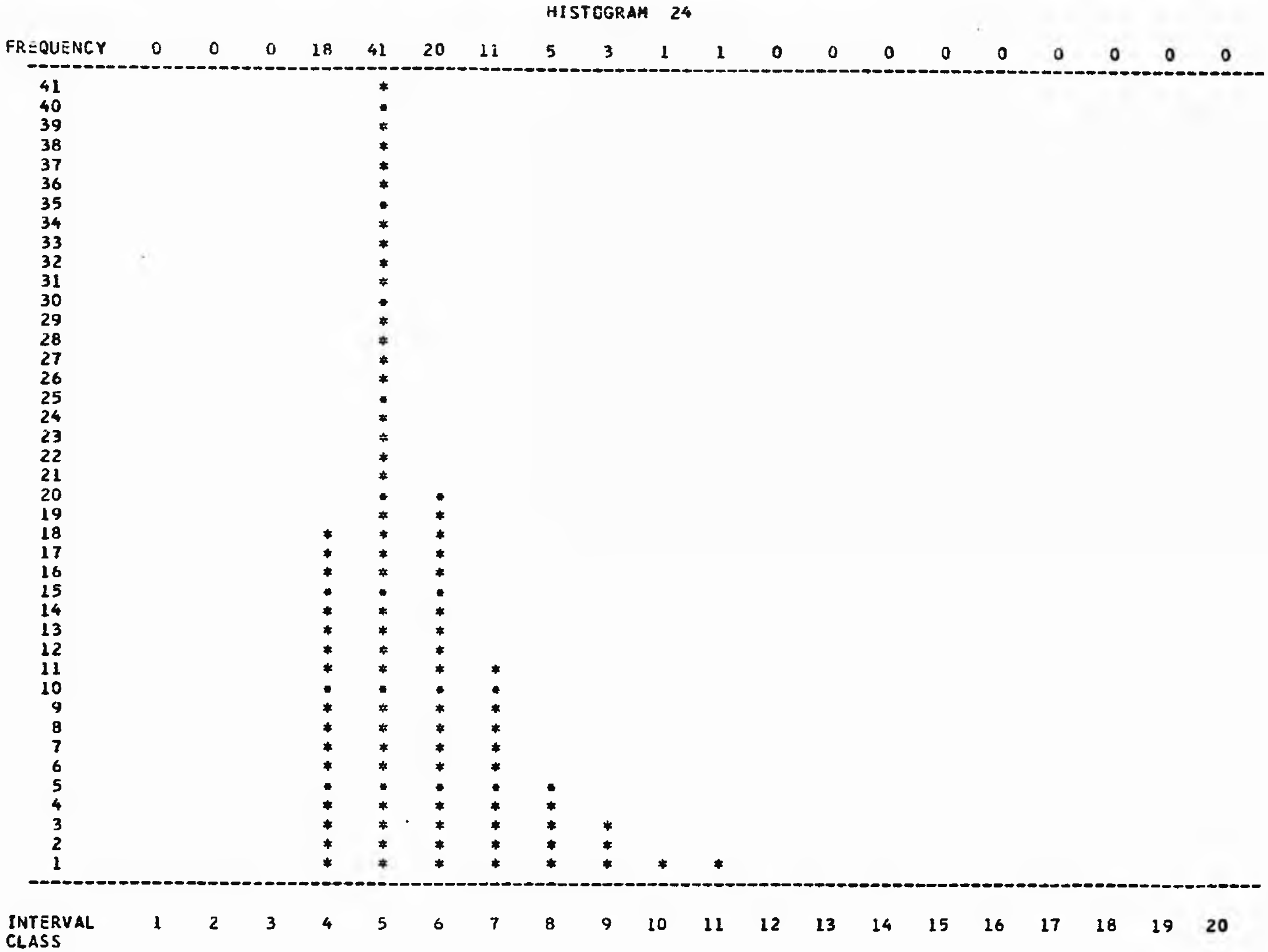


Fig. 124. Histogram for flatness of pebbles from site five of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.540	0.180	0.424	1.345	9.130

HISTOGRAM 25

```
FREQUENCY       0    2    8    8   12   11   13    9   13    6    7    5    1    3    1    1    0    0    0    0
        ----------------------------------------------------------------------------------------------------
     13                                       *         *
     12                             *         *         *
     11                             *    *    *         *
     10                             *    *    *         *
      9                             *    *    *    *    *
      8                   *    *    *    *    *    *    *
      7                   *    *    *    *    *    *    *         *
      6                   *    *    *    *    *    *    *    *    *
      5                   *    *    *    *    *    *    *    *    *    *
      4                   *    *    *    *    *    *    *    *    *    *
      3                   *    *    *    *    *    *    *    *    *    *         *
      2              *    *    *    *    *    *    *    *    *    *    *         *
      1              *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
        ----------------------------------------------------------------------------------------------------

INTERVAL        1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
CLASS
```

Fig. 125. Histogram for roundness of pebbles from site five of fan FX-I.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
344.407	23495.199	153.281	0.513	5.362

```
                                HISTOGRAM  28

FREQUENCY    0   0   0   0   0   0   2   1   6  13  12  12   6  20   9   7  10   1   1   0
---------------------------------------------------------------------------------------------
  20                                                             *
  19                                                             *
  18                                                             *
  17                                                             *
  16                                                             *
  15                                                             *
  14                                                             *
  13                                             *               *
  12                                             *   *   *       *
  11                                             *   *   *       *
  10                                             *   *   *       *           *
   9                                             *   *   *       *   *       *
   8                                             *   *   *       *   *       *
   7                                             *   *   *       *   *   *   *
   6                                         *   *   *   *   *   *   *   *   *
   5                                         *   *   *   *   *   *   *   *   *
   4                                         *   *   *   *   *   *   *   *   *
   3                                         *   *   *   *   *   *   *   *   *
   2                                 *       *   *   *   *   *   *   *   *   *
   1                                 *   *   *   *   *   *   *   *   *   *   *   *   *
---------------------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 126. Histogram for sphericity of pebbles from site one of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.620	0.018	0.134	-0.016	4.230

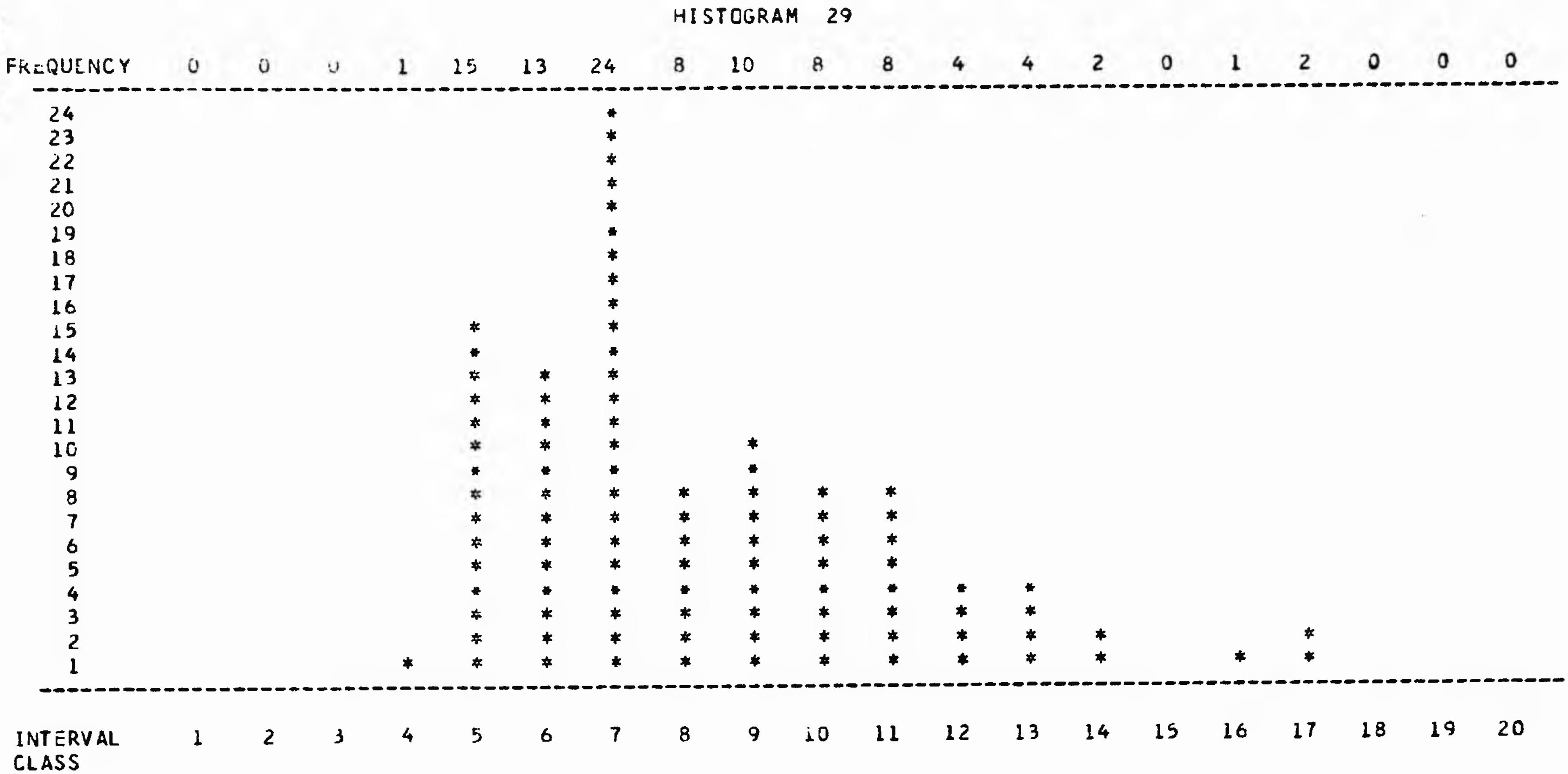


Fig. 127. Histogram for flatness of pebbles from site one of fan FY-II.

Moment measures

Mean	Variance	Stan.Dev.	Skewness	Kurtosis
2.314	0.710	0.843	1.062	7.658

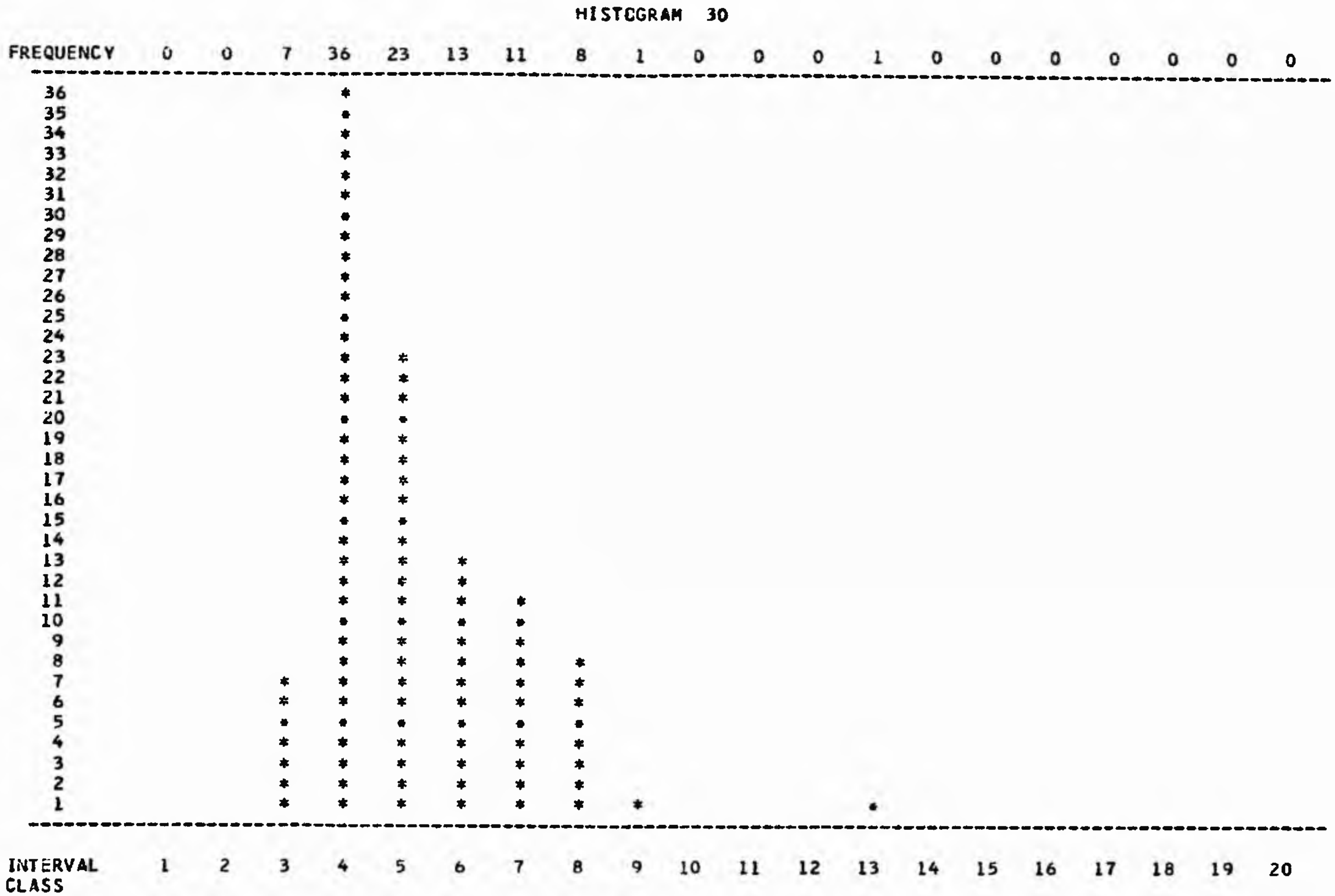


Fig. 128. --Histogram for roundness of pebbles from site one of fan FY-II.

MUMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
231.828	6429.191	80.182	1.310	11.767

HISTOGRAM 33

```
FREQUENCY    0   0   0   0   0   0   0   1   4   5  16  12  12  13  17  11   4   5   0   0
--------------------------------------------------------------------------------------------
    17                                                          *
    16                                              *           *
    15                                              *           *
    14                                              *           *
    13                                              *           *   *
    12                                              *   *   *   *   *
    11                                              *   *   *   *   *   *
    10                                              *   *   *   *   *   *
     9                                              *   *   *   *   *   *
     8                                              *   *   *   *   *   *
     7                                              *   *   *   *   *   *
     6                                              *   *   *   *   *   *
     5                                          *   *   *   *   *   *   *       *
     4                                      *   *   *   *   *   *   *   *   *   *
     3                                      *   *   *   *   *   *   *   *   *   *
     2                                      *   *   *   *   *   *   *   *   *   *
     1                                  *   *   *   *   *   *   *   *   *   *   *
--------------------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 129. Histogram for sphericity of pebbles from site two of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.643	0.014	0.120	-0.004	4.187

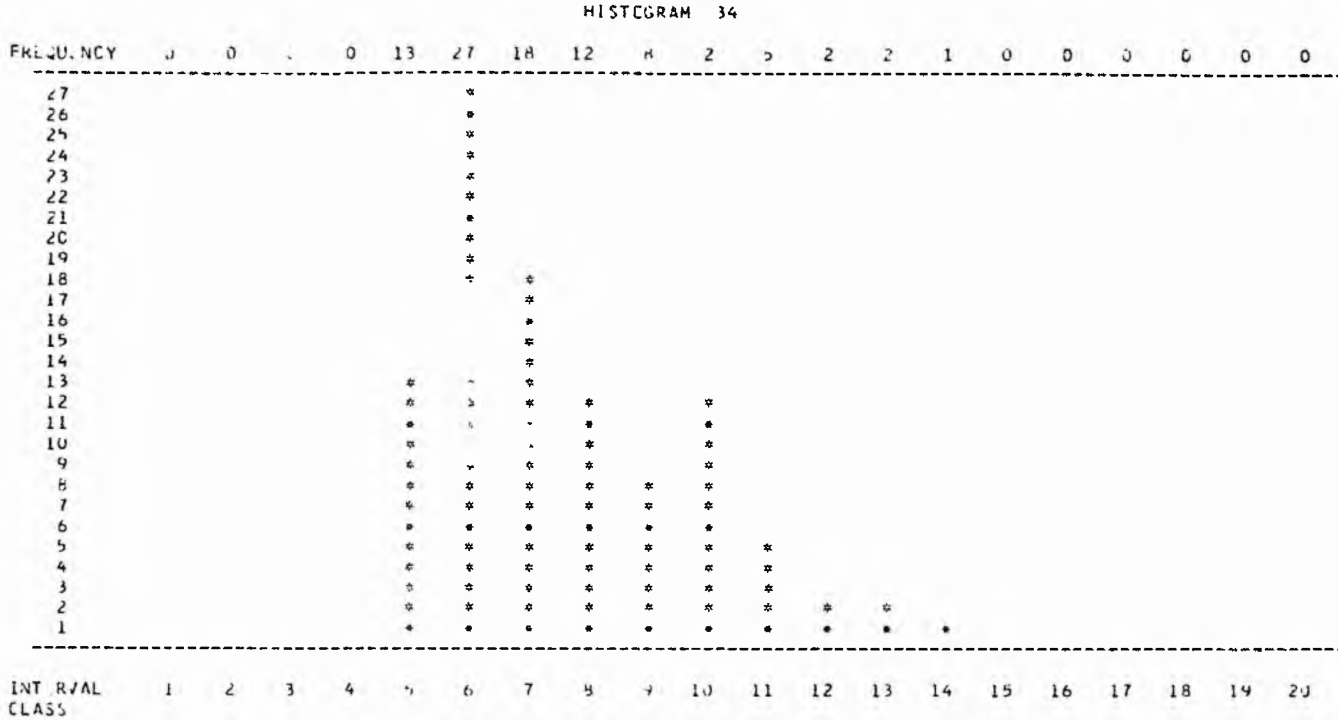


Fig. 130. Histogram for flatness of pebbles from site two of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
2.127	[illegible].41[illegible]	0.640	[illegible].835	6.042

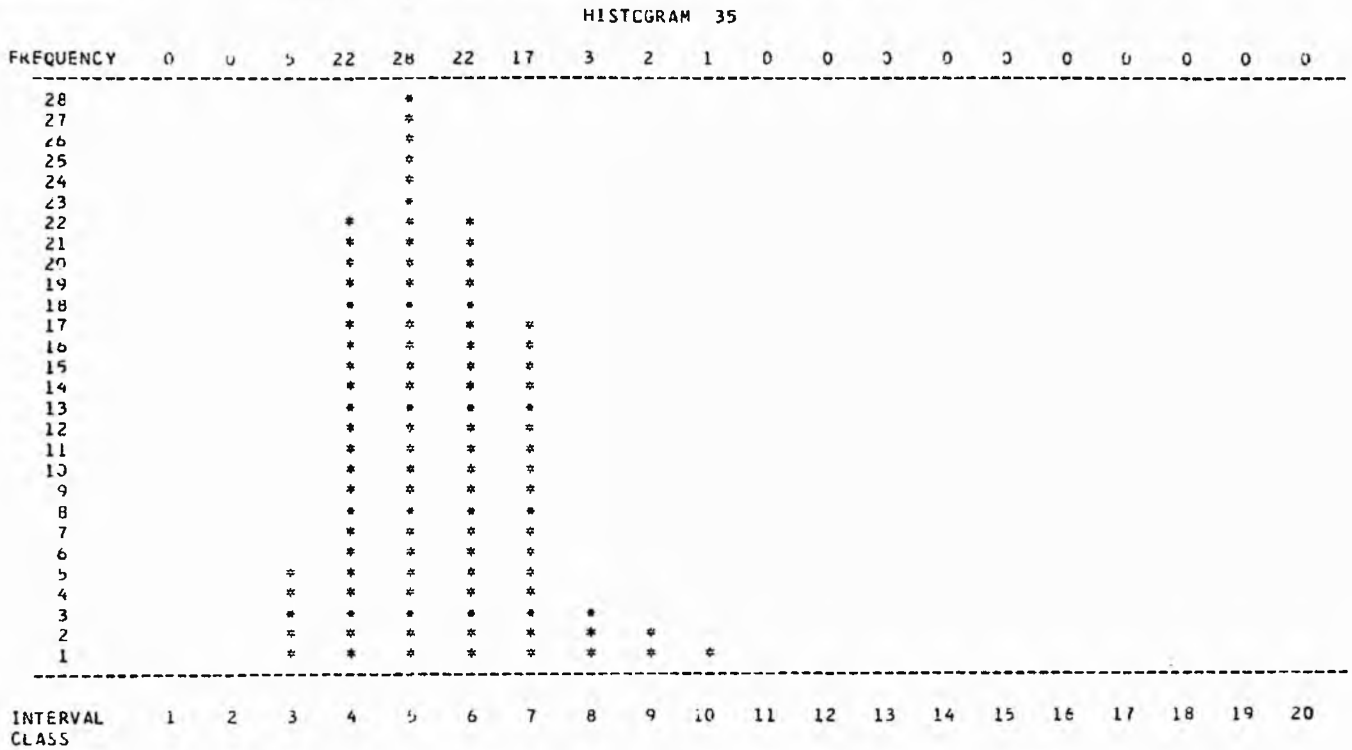


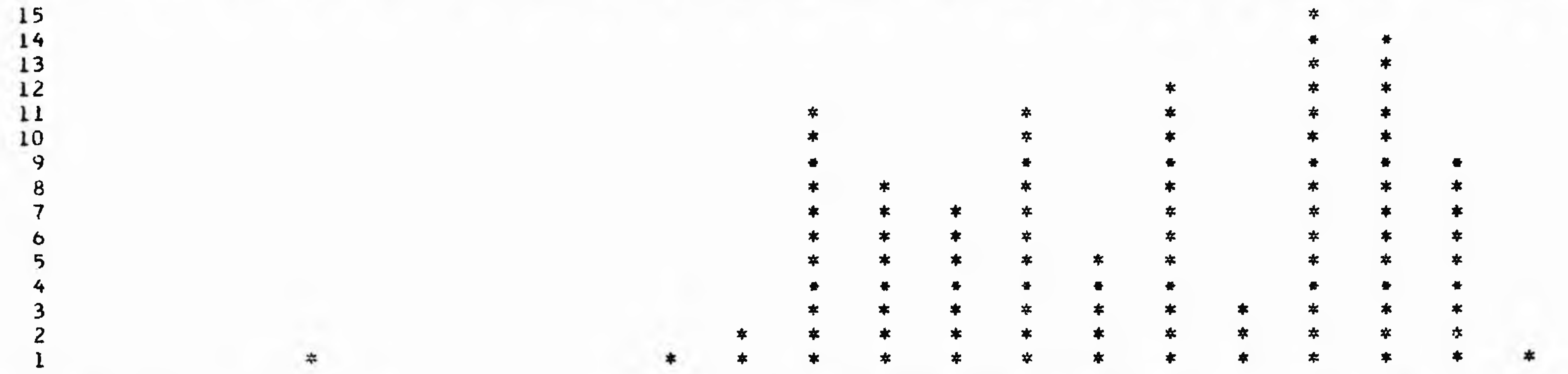
Fig. 131. Histogram for roundness of pebbles from site two of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
248.909	4842.676	69.589	0.459	5.231

HISTOGRAM - 38

FREQUENCY	0	0	1	0	0	0	0	1	2	11	8	7	11	5	12	3	15	14	9	1



INTERVAL CLASS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Fig. 132. Histogram for sphericity of pebbles from site three of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.699	0.028	0.169	-0.444	5.376

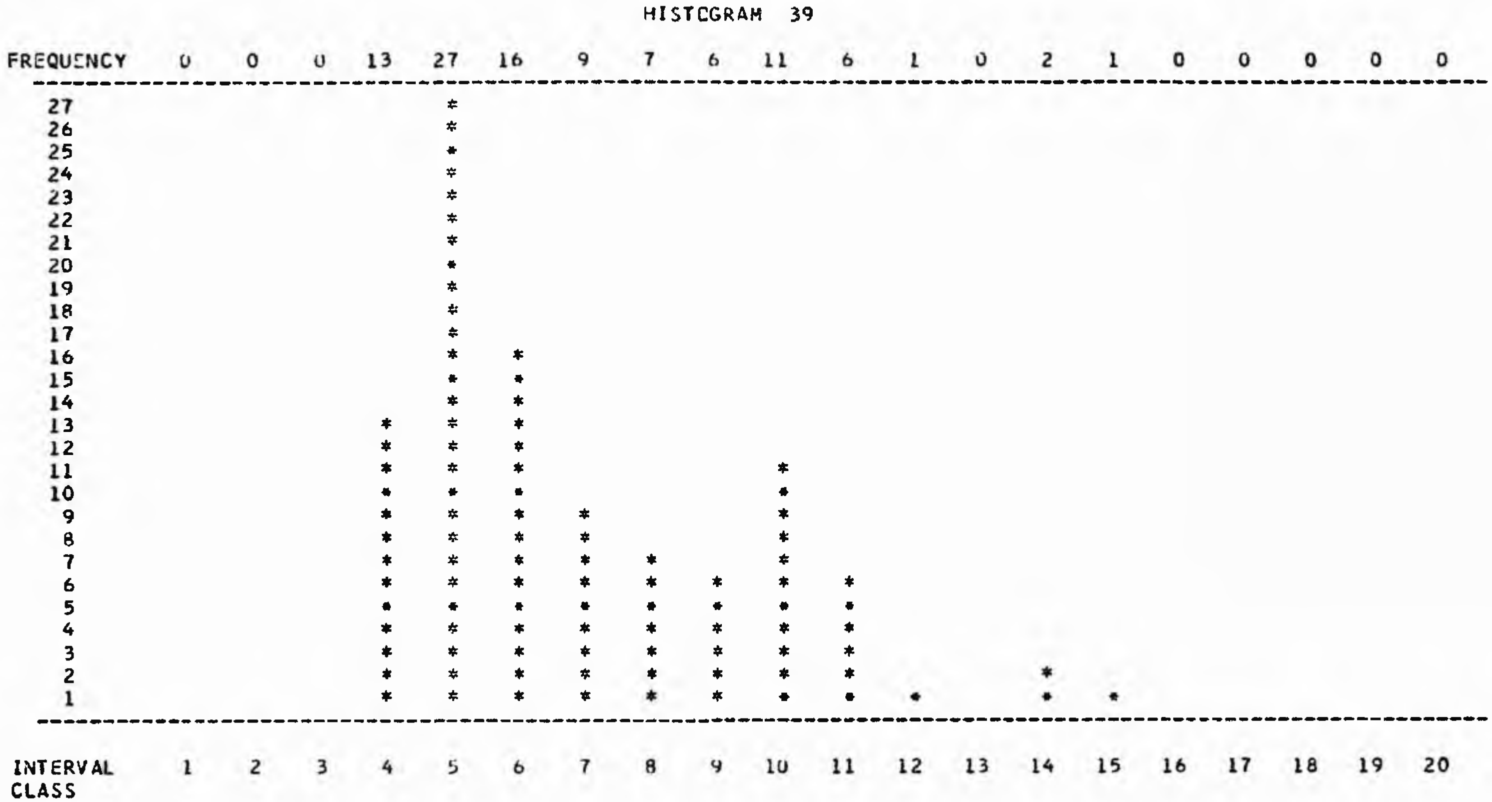


Fig. 133. Histogram for flatness of pebbles from site three of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
2.366	19.795	4.449	9.265	180.783

```
                                HISTOGRAM  40

FREQUENCY    1   1  10  25  16  11   8   6  16   2   3   0   0   1   0   0   0   0   0   0
------------------------------------------------------------------------------------------
    25                  *
    24                  *
    23                  *
    22                  *
    21                  *
    20                  *
    19                  *
    18                  *
    17                  *
    16                  *   *               *
    15                  *   *               *
    14                  *   *               *
    13                  *   *               *
    12                  *   *               *
    11                  *   *   *           *
    10              *   *   *   *           *
     9              *   *   *   *           *
     8              *   *   *   *   *       *
     7              *   *   *   *   *       *
     6              *   *   *   *   *   *   *
     5              *   *   *   *   *   *   *
     4              *   *   *   *   *   *   *
     3              *   *   *   *   *   *   *       *
     2              *   *   *   *   *   *   *   *   *
     1       *   *  *   *   *   *   *   *   *   *   *           *
------------------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 134. Histogram for roundness of pebbles from site three of fan FY-II.

```
MOMENT MEASURES

    MEAN       VARIANCE       STAN. DEV.       SKEWNESS       KURTOSIS
  268.731     15043.977        122.654          0.673          5.929
```

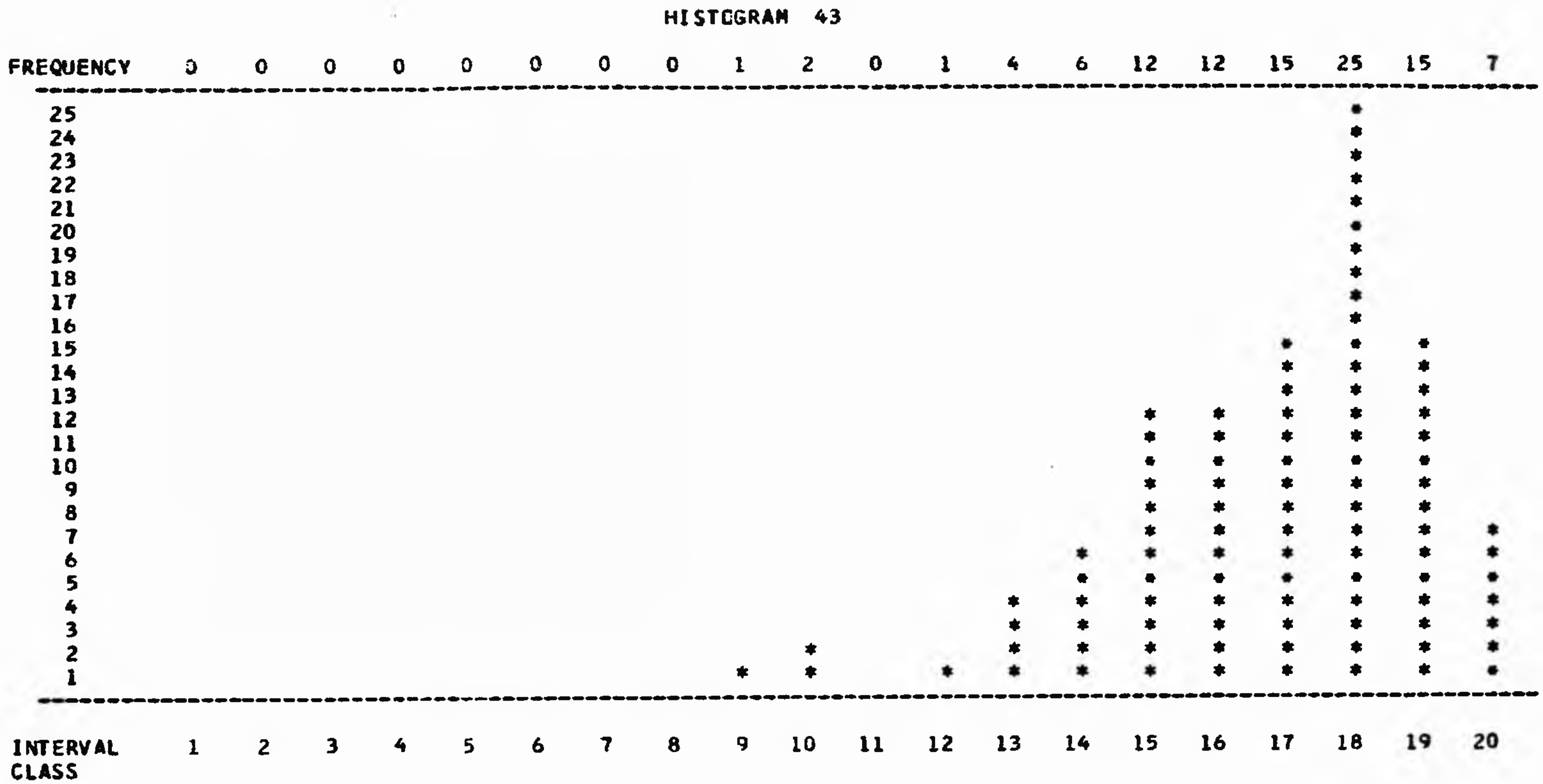


Fig. 135. Histogram for sphericity of pebbles from site four of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.814	0.013	0.112	-1.034	8.072

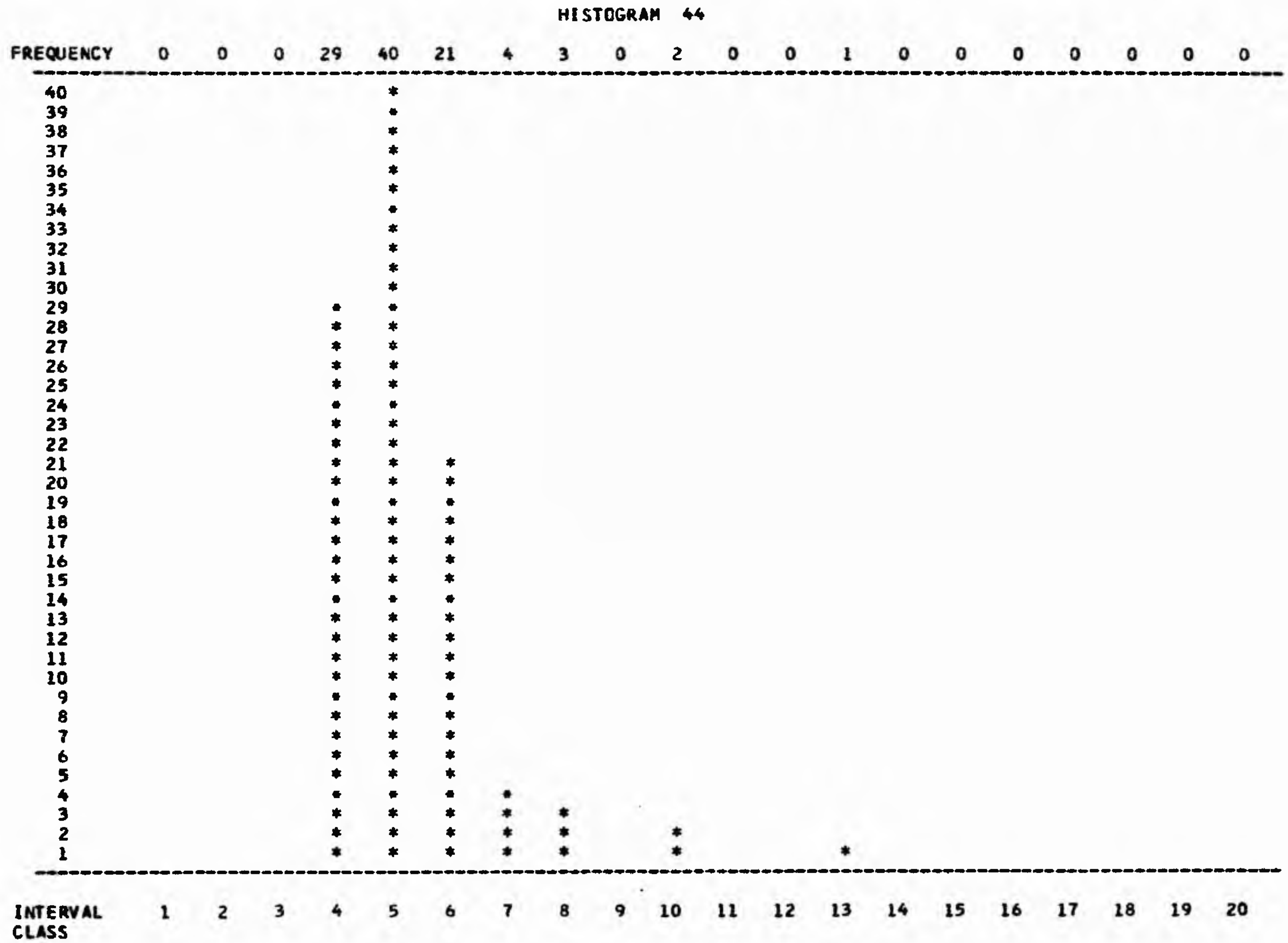


Fig. 136. Histogram for flatness of pebbles from site four of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.431	0.166	0.408	2.644	24.366

```
                           HISTCGRAM  45

FREQUENCY    0   0   3   6   9  16  14  12  13   8   7   3   3   4   2   0   0   0   0   0
----------------------------------------------------------------------------------------------
   16                            *
   15                            *
   14                            *   *
   13                            *   *       *
   12                            *   *   *   *
   11                            *   *   *   *
   10                            *   *   *   *
    9                        *   *   *   *   *
    8                        *   *   *   *   *   *
    7                        *   *   *   *   *   *   *
    6                    *   *   *   *   *   *   *   *
    5                    *   *   *   *   *   *   *   *
    4                    *   *   *   *   *   *   *   *           *
    3                *   *   *   *   *   *   *   *   *   *   *   *
    2                *   *   *   *   *   *   *   *   *   *   *   *   *
    1                *   *   *   *   *   *   *   *   *   *   *   *   *
----------------------------------------------------------------------------------------------

INTERVAL     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
CLASS
```

Fig. 137. Histogram for roundness of pebbles from site four of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
370.831	20072.848	141.679	0.534	5.258

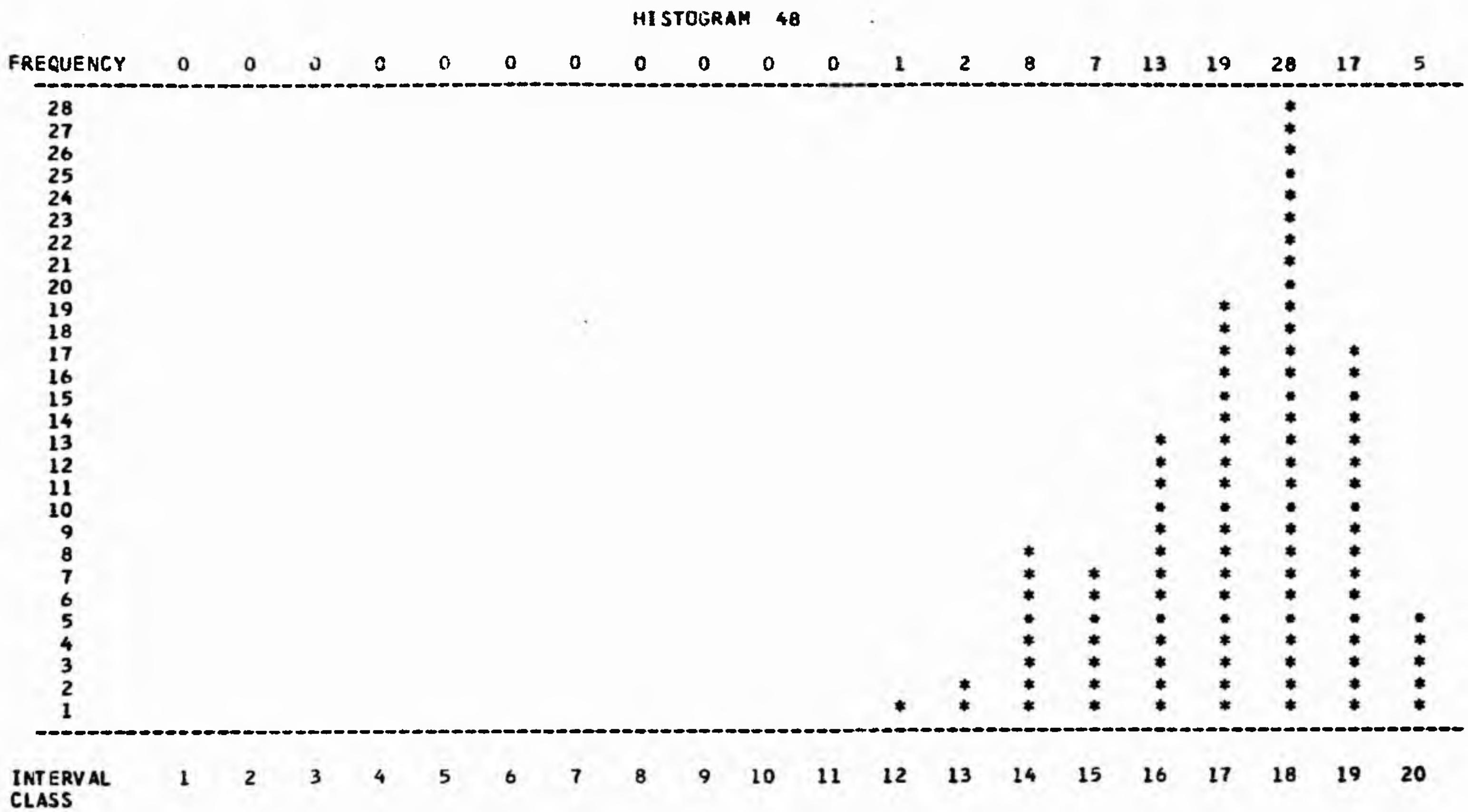


Fig. 138. Histogram for sphericity of pebbles from site five of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
0.831	0.008	0.087	-0.615	5.389

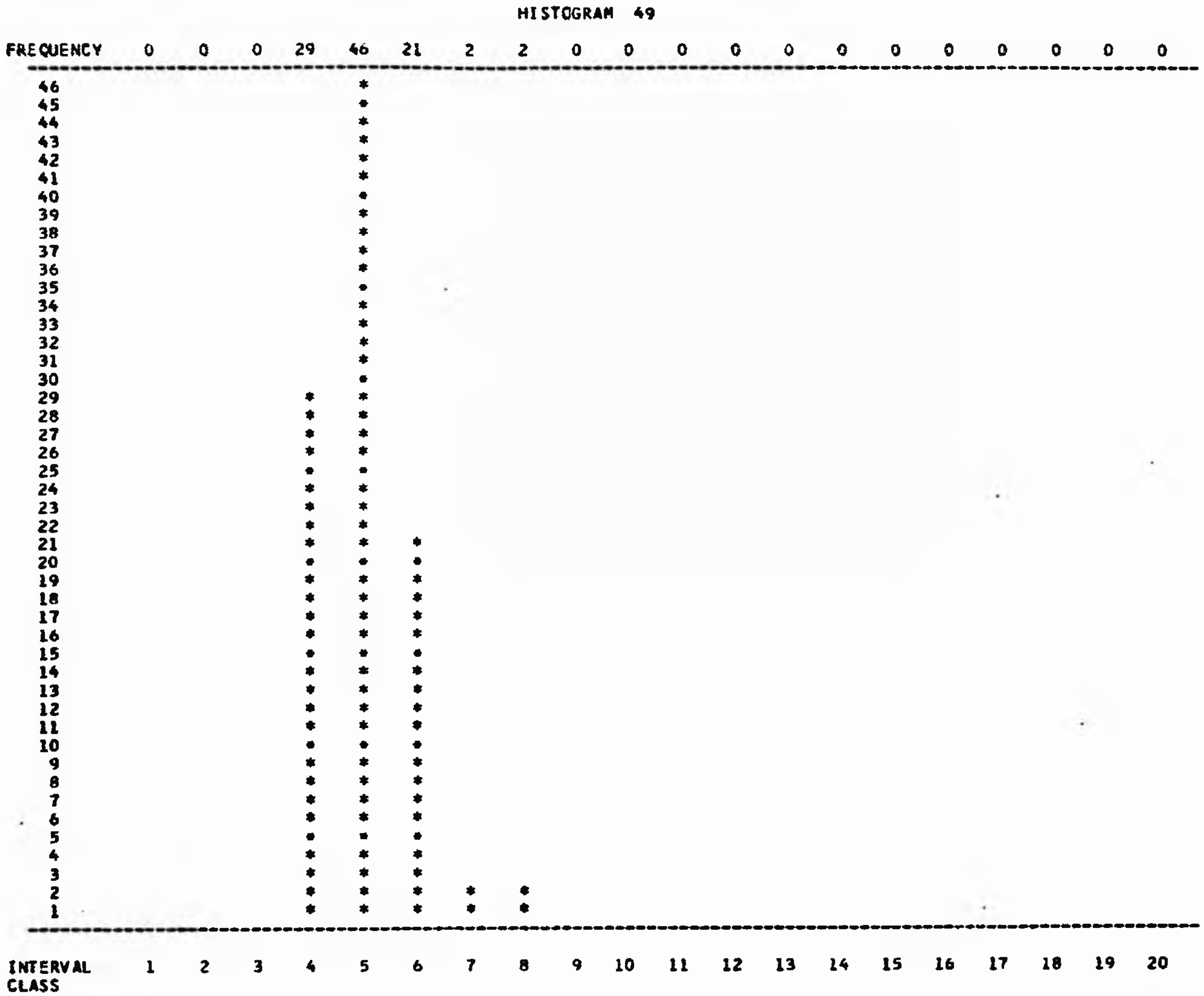


Fig. 139. Histogram for flatness of pebbles from site five of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
1.354	0.058	0.240	1.213	8.479

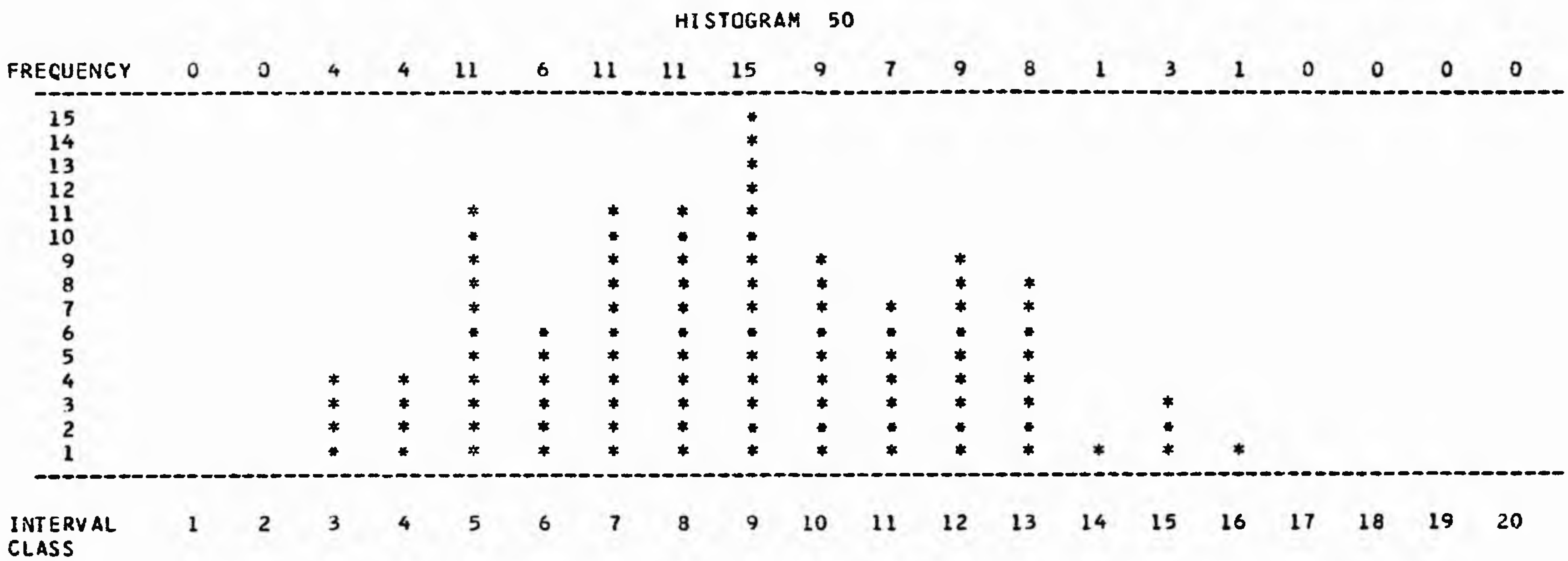


Fig. 140;- Histogram for roundness of pebbles from site five of fan FY-II.

MOMENT MEASURES

MEAN	VARIANCE	STAN. DEV.	SKEWNESS	KURTOSIS
408.979	23895.926	154.583	0.115	4.573

Plate 1. Part of Najd pediplain between Musayqirah and Tabrak.

Plate 2. Weathered granite producing inselberges and pediments between Al-Quway iyah and Qudayan.

Plates 3 & 4. Khashm Qraydan pediment showing the relationship between older and younger surfaces.

Plate 5. Surface material near the mountain front at Khashm Qradan pediment.

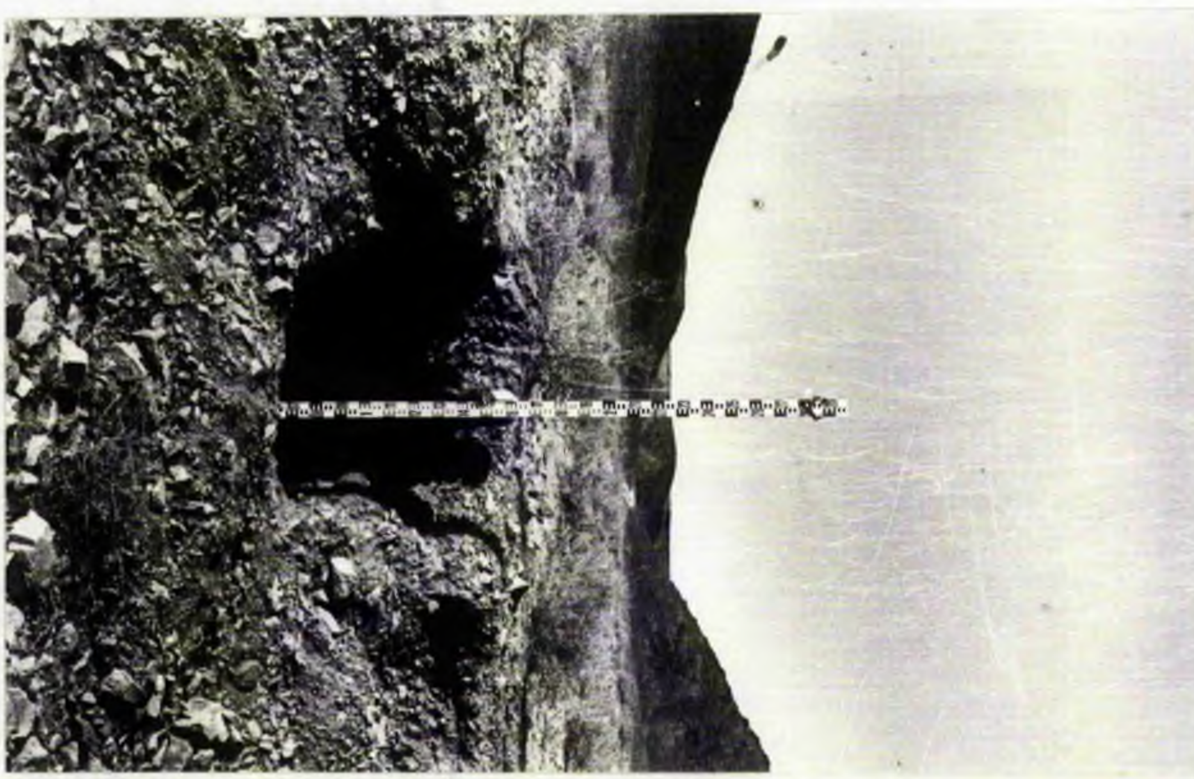
Plate. 6. Wadi Al-Quway iyah from the north. This wadi acts as a local base level for pediment development.

Plates 7 & 8. Surface material near the mountain front at Wadi Al-Quway iyah pediment.

Plates 9 & 10. Surface material of fan FXI and fan FYII east of jebal Umm ad Dabah.

Plates 11 & 12. Surface deposits near the apex of the alluvial fans east of jebal Umm ad Dabah.

Plates 13 & 14. Near surface material showing the amount of large [illegible]
particles nera the apex of the fans east of jebal
Umm ad Dabah.



Plates 15 & 16. A phase of deposition shown in a cross section at 1200m sites of fan FXI and fan FYII.